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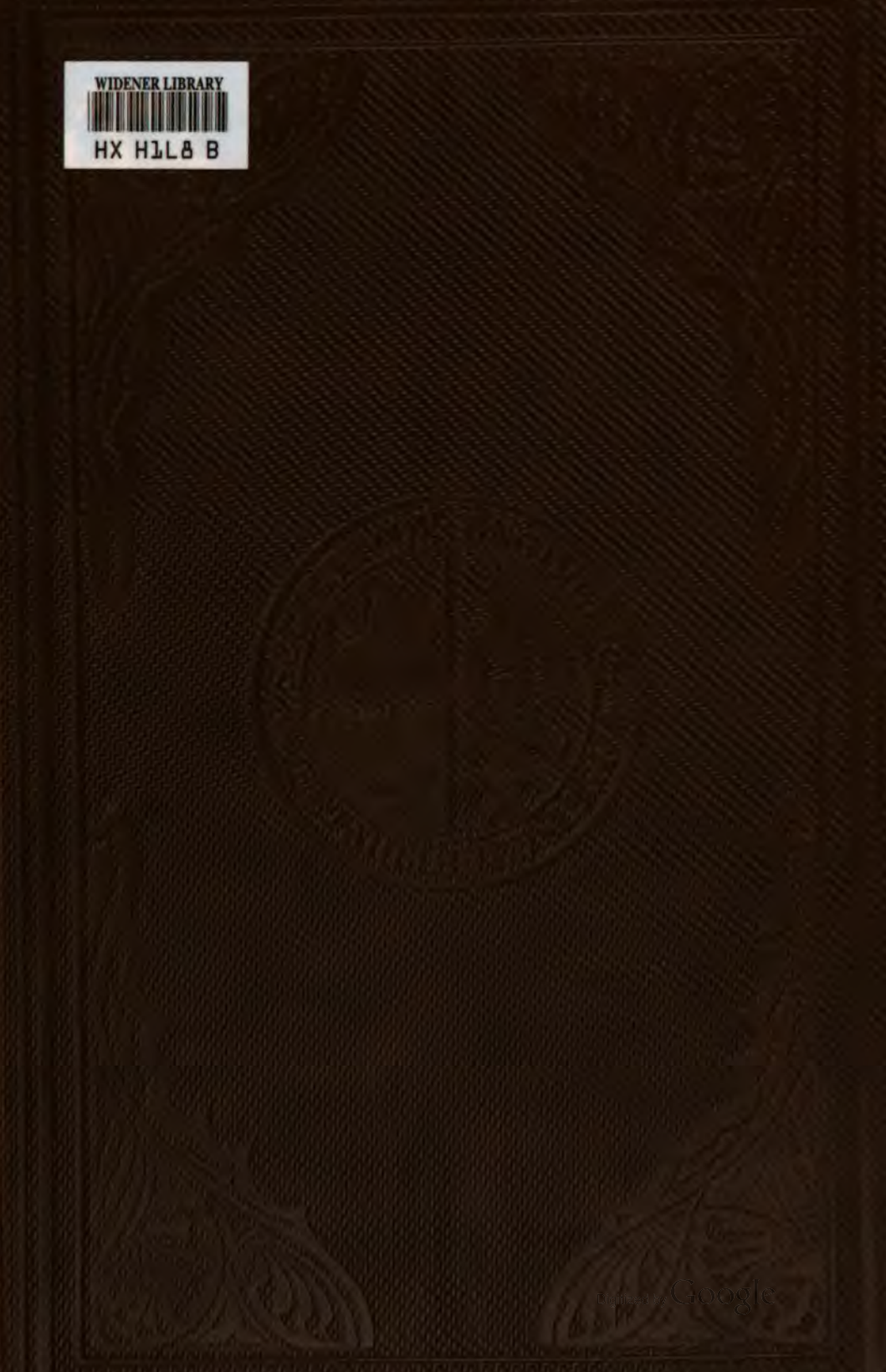

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SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

TRANSACTIONS FOR 1877.

EDITED BY

PERRY F. NURSEY, MEMB. SOC. ENG., SECRETARY.

PLACE OF MEETING AND OFFICES:

THE SOCIETY'S HALL, No. 6, WESTMINSTER CHAMBERS,
VICTORIA STREET, WESTMINSTER.

LONDON:
E. & F. N. SPON, 46, CHARING CROSS.
NEW YORK:
446, BROOME STREET.
1878.

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PREMIUMS FOR 1877.

At a meeting of the Society, held on February 4th, 1878, Premiums of Books were awarded to:

J. WALTER PEARSE, for his Paper "On the Mechanical Firing of Steam Boilers."

ALFRED LE GRAND, for his Paper "On Tube Wells."

RALPH H. TWEDDELL, for his Paper "On Direct-Acting Hydraulic Machinery."

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T. R. MORGAN, SR.,
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CONTENTS.

	PAGE
Inaugural Address of the President, Thomas Cargill	1
The Mechanical Firing of Steam Boilers. By J. Walter Pearse	31
The Mechanical Firing of Steam Boilers. Adjourned Discussion	49
The Priming of Steam Boilers. By William Major	59
Direct-Acting Pumping Engines. By Philip B. Bjöerling ..	79
Direct-Acting Hydraulic Machinery. By Ralph H. Tweddell	95
Rural Sanitation. By G. W. Usill	113
Tube Wells. By Alfred Le Grand	133
Tube Wells for Large Water Supplies. By Robert Sutcliff	149

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SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

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1878.

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T. R. MORGAN, SR.
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TRANSACTIONS, &c.

February 5th, 1877.

INAUGURAL ADDRESS.

By THOMAS CARGILL, PRESIDENT.

BEFORE proceeding to the more immediate purport of my address, I have, first, to thank you for the honour you have conferred upon me, in electing me to the important and responsible position of President of your Society. To enable me to discharge faithfully and zealously the duties of my office, I count, with confident expectation, upon the hearty support and co-operation of my colleagues at the Council Board, and upon the cordial assistance of the members of the Society collectively. I have been too long connected with this and other similar societies of a professional and scientific character, not to be well aware that, however earnest and well directed may be the endeavours of the few, they are of comparatively little avail, and fall short of their object, unless they are seconded by efforts, equally energetic, on the part of the many. The members of the Council and myself are on the present occasion the few. You, gentlemen, are the many. As the representative of the former, it is to you then that I look for prompt and active assistance in performing the duties of the chair.

I rest assured that if you continue, and if we all continue, to evince, as hitherto, a lively and genuine interest in the welfare and prosperity of the Society, it will develop and flourish under my hands, as it has done under those of my predecessors. I take your promise of assistance and support as given, and in return I give you mine, that so far as my professional avocations will permit, the affairs of the Society and the obligations of my position shall always be to me an object of deep regard and solicitude, and claim my constant care and consideration. I confidently trust, therefore, that by our united efforts, my year of office will be rendered agreeable to myself, satisfactory to the members, and beneficial to the Society.

For some time past, it has been the custom of our Presidents to lay before the members of the Society, on these occasions, a

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brief résumé of the most noteworthy features which have attended its proceedings during the bygone year, as well as a concise statement of its numerical, professional, and financial condition. I consider this a practice far too excellent to be departed from, inasmuch as it affords an opportunity, not only of reminding the members of the advantages which they enjoy, and the obligations which devolve upon them, but of proving to the world at large, that the operations of the Society and the benefits it confers are of a solid, tangible, and permanent character. I therefore claim your attention for a short time, while I place before you an abstract of the subjects to which I have just alluded.

The session opened with a paper by our esteemed Secretary, on the Channel Railway. The various schemes, having for their immediate and common object, the removal of the obstacles presented by the "silver streak," and thus binding still closer the links of the "entente cordiale," were generally described, and their leading features adverted to. This communication was rewarded with an adjourned discussion, which turned principally upon the rival merits of tunnels and tubes, and in which both plans found warm advocates.

A paper on "Air Compression," by Mr. J. Steel, next occupied our attention. In it, the numerous purposes to which the principle of "compressed air" could be economically and advantageously applied, were successively pointed out. There can be very little doubt that, notwithstanding the extensive use already made of compressed air by engineers, there is still a large field open for its application.

Mr. Steel's communication was followed, at our ensuing meeting, by two others of a somewhat kindred character. One was entitled "Flues and Ventilation," by Mr. A. H. C. Trewman, and the other "The Ventilation of Buildings," by Mr. J. W. Pearse.

It might be inferred that the contents of these two papers possessed more interest for architects than engineers. Indeed, so far as the ventilation of dwelling-houses is concerned, the subject does not properly fall within the province of an engineer. Judging, however, from the discussion which ensued, it is clear that our profession takes very considerable interest in everything that relates to ventilation, whether on a large or small scale. Many and ingenious were the plans which were described for overcoming the well-known difficulties attendant upon the ventilation of public buildings, where large numbers of human beings are in the habit of congregating. Although a good deal has been effected towards remedying defects, it must

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yet be acknowledged, that a good deal more remains to be accomplished, before we can be said to have arrived at a perfect system of ventilation.

At the close of the summer session Mr. Henry Davey read a paper of a very practical nature upon "The Underground Pumping Machinery at the Erin Colliery, Westphalia." The engines used in this instance are of the compound differential type, and constitute the largest examples extant under similar circumstances. Working models of the machinery accompanied the communication, and some very interesting details, in connection with this class of engine, were elicited during the discussion.

Passing over the recess, which was very profitably and agreeably employed in a manner to which I shall presently have to direct your attention, the first paper read at the commencement of our winter meeting was by Mr. Conradi, and treated of the subject of stone-sawing machinery. The ordinary stone-sawing machines, worked by hand, were noticed, as well as the improved machinery employed for cutting and dressing the stone of which the new Law Courts are being built. The system used in France was also described, and during the discussion several improvements were introduced to the notice of the members, which were considered worthy of further attention and investigation.

The conversion of peat, cut in a raw state from the bog, into fuel, has for very many years occupied the attention of both engineers and chemists, and the paper read before us by Mr. C. E. Hall, on the "Conversion of Peat into Fuel and Charcoal," proved, by the warm discussion which ensued, that the subject has lost none of its importance or attractiveness. Preference was given to the system of condensation over that of compression. It must be acknowledged, that hitherto but very small success has attended all attempts to make projects of this character remunerative. The real reason of the many failures which have taken place, may probably be found in the circumstance, that the best machinery and the appliances most suitable for the work, have either not yet been invented or not adopted. One of the objects of the author was to draw attention to some new and improved machinery, from the use of which, better results were anticipated.

A communication on the "Rolling of Ships" by Mr. William McNaught brought to a close the ordinary meetings of last year. After alluding to the severe strains to which ships were subjected, in consequence of rolling and lurching, Mr. McNaught proposed a remedy in the form of one or two balanced rudders

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under the bottom of the ship, which could be withdrawn into the ship when not wanted, or when in shallow water. The principle enunciated is very similar to what are known as bilge keels. The surface acted upon by the balanced rudders is, however, very much less, so that it is a question whether the efficiency would not diminish in the same proportion. Experiment alone is capable of deciding this point.

One of the most prominent and most useful features of the Society of Engineers, is to be found in the manner in which arrangements are made for utilizing the recess to the advantage of the members. This recess, or temporary relaxation of the ordinary routine business, is common to all societies kindred to our own, and in their instance virtually signifies, for the time being, an almost total cessation of their vitality.

The Society of Engineers, on the contrary, avails itself of these very periods to enable its members, and any friends who may accompany them as visitors, to acquire an amount of practical knowledge and information, which I am not exaggerating, when I state, is not to be acquired through any other channel. It has been the custom of the Council, ever since the foundation of the Society, to organize, annually, a certain number of visits to such engineering operations, works, and establishments within a reasonable distance of the metropolis, as may seem the best suited to afford instruction to the members. A marked success has attended this annual practice. Not only Government establishments, but others of an equally important and extensive character, are thrown open to our inspection, and it frequently happens that some, who would close their doors to individuals in their private capacity, freely open them to those entering under the auspices of the Society. The advantage of those professional visits, especially to pupils and assistants, can scarcely be overestimated. Not only are they thus enabled to visit works belonging to one or other of the branches of civil engineering, and to witness mechanical operations, and chemical processes, access to which under other conditions would be difficult, if not impossible, but they have a far larger range open to their inspection, and a wider field from which to glean practical information, than could be afforded in the office, or in the works of the most eminent engineer in the kingdom. Another very valuable result attending these visits, is that it brings our professional information down to date. The invention of man is inexhaustible. New machinery is constantly superseding old, and improved means and fresh appliances, for accomplishing the same operations, are introduced every day. It is on works, and on works

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alone, of importance and magnitude, and in engineering establishments upon a large scale, that these new and improved methods are, in the first instance, to be witnessed, and it is under those novel and favourable conditions in which they are viewed by the members of our Society.

Our summer excursions, if I may so term the series of annual visits to which I have just drawn your attention, commenced rather earlier in the season then usual. On the 15th of May last, we assembled at the Glaciarium at the King's Road, Chelsea, to witness and practically test the formation of a large sheet of ice fully adapted for the purposes of skating. Mr. John Gamgee has since applied the same principle, with complete success, upon a larger scale at the Charing Cross Baths, and has also erected at Manchester a Glaciarium containing a still more extensive area of ice, frozen by artificial congelation. Upon the same day, the party proceeded to the Stanley Works, situated also in King's Road, and by permission of Messrs. A. Ransome and Co. were shown, among other objects of interest, some special wood-working machinery in motion. Subsequently the members and their friends inspected the Oakley Works in the same locality, where examples of similar machinery were exhibited, through the courtesy of Messrs. S. W. Worssam and Co. A visit to the Manor Works and Statue Foundry of Messrs. R. Masefield and Co. brought the excursion to a close.

In the following month, the Directors of the London Small Arms Company accorded permission to the Society to go over their works at Bow, where some alterations were being carried out by order of the Government, in connection with the manufacture of the Martini-Henry rifle. These alterations necessitated some changes and modifications in the Company's plant, which were in progress at the time of the visit. Advantage was taken of the remainder of the day to inspect the Paper Staining Works of Messrs. John Allen and Son, which were conveniently situated in the same neighbourhood.

Early in July, arrangements were made, through the courtesy of Mr. A. M. Rendel, Consulting Engineer to the Company, for an excursion to the Victoria Dock Extension, one of the most important works of engineering in progress in the kingdom. The party were received with every attention and cordiality by the resident engineer, Mr. A. C. Andros, M.I.C.E., and Mr. Colson, engineer for the contractors, Messrs. Lucas and Aird. This work is of a very extensive character, and includes 3,000,000 cubic yards of excavation, 200,000 cubic yards of concrete, and 30,000 tons of cement. The dock walls are to be built of concrete,

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and the gates will be of iron. By this extension the Company obtains, in addition to the large increase of dock area, storage and wharfage room, a new entrance to the river lower down stream, where the navigation becomes less impeded. It is the intention of the Society, with the permission of the Company's Engineer, to visit this great work again this year.

The Royal Victoria Victualling Yard, Deptford, furnished us with an object for our next visit in August. Here were shown the cask making, the hydraulic and sawing machinery, the steam bakery, and the mills for grinding mustard, chocolate, and other necessaries and condiments.

Our concluding excursion for the season was made in September last. First, we inspected the Works of the Thames Steam Ferry Company at Wapping, and afterwards proceeded down the river to the establishment of Messrs. Westwood, Baillie, and Co., at London Yard, Isle of Dogs. Here was in progress of construction the largest swing bridge as yet designed. It is intended for Port Adelaide, and has a swinging weight of 600 tons.

Before leaving this subject, I would earnestly impress upon the members, and particularly the younger ones, the great practical benefit which will accrue to them from a close attendance at these visits. Independently of the individual advantages which they receive, the whole Society benefits collectively by the results of these excursions. They serve to fill up the hiatus which is caused by the unavoidable suspension of routine business during the summer months, and they serve, moreover, to bring the members into more intimate communion with one another. Social and professional ties are often thus cemented to mutual advantage, and relationships thus established, have frequently developed into sincere and lasting friendships.

We have every reason to congratulate ourselves on the numerical attendance of our visits of last year; but I trust, nevertheless, that you will respond to my appeal, and that I shall have the pleasure, as your President, of accompanying still larger numbers, on similar excursions, during my year of office.

In accordance with the statement made at the commencement of my address, I have now to lay before you some further particulars in connection with the Society, which cannot fail to be of the deepest interest to us all. Nearly a quarter of a century ago, a small community, or scientific club, was formed for the purpose of holding meetings and reading and discussing papers. It was at first mainly intended for the young members of the profession, but it gradually grew and increased until,

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under the title of the Society of Engineers, it acquired its present professional and social status. It has had for some time past a Meeting Hall of its own. It has a library and room for the use of the members. It exchanges its Transactions with those of the Institution of Civil Engineers, and with those also of all the professional, scientific, and philosophical societies, both at home and abroad, which have risen to any degree of eminence. Many of its members have been elected members of the Institution of Civil Engineers, and have risen to the highest positions in the profession. You have already heard from our Secretary, at the Annual General Meeting, a statement of our financial affairs, which, I am happy to say, are in a very sound and prosperous condition.

There is also another very important circumstance upon which we have good reason to congratulate ourselves. It is, that at some considerable expense, which succeeding events have proved to have been most judiciously incurred, we have published our Transactions down to date. The volume for last year is already in the press, and will shortly be issued to the members. Our numerical efficiency has been exceedingly well maintained. The total number of members of all classes elected during the past year amounted to fifty-three, which is a greater number than has ever been previously attained. I would take this opportunity of urging upon you, that your zeal for the interests of the Society, and the good you can confer upon it, cannot be better demonstrated than by the introduction of new members amongst us.

I have with regret to announce to you, that we have lost one of our honorary members by death during last year. The gentleman in question, Mr. Robert Napier, the eminent shipbuilder, of the firm of Robert Napier and Sons, died at Shandon at the ripe old age of eighty-five years. Born in comparatively humble circumstances, he gave his attention exclusively to mechanical and marine engineering, and was engaged in fitting up the machinery of her Majesty's ship, the 'Duke of Wellington,' at that time the largest ship in the British navy. In 1853, Mr. Napier took his sons into the firm, under the title of Robert Napier and Sons. They undertook for the Admiralty the contract in 1859 for the 'Black Prince,' in 1860 for the 'Hector,' and have also constructed several steel rams and ironclad ships of war for foreign governments.

We unquestionably enjoy the distinction of being the first nation to introduce and adopt the present system of railway engineering. We were the pioneers of steam locomotion in France and on the Continent generally, and are still actively

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engaged in carrying into far distant lands, the advantages which that system has conferred upon ourselves, by constituting it the most prominent of our internal resources.

It is true that we shall never witness another "railway mania." Our great arterial lines are all laid out, and laid out with sufficient accuracy and precision to act as such. At intervals, loop and branch lines are constructed, but they are rather to be regarded as evidences of an increase in traffic and population, than as necessitated by the inadequacy of their predecessors. That many of our main lines require widening, and even doubling in certain localities, is too well known to require comment; but that is a very different affair from the actual construction of an entirely new and extensive route of intercommunication.

The principal feature of interest to chronicle with respect to the recent development of our railway system, is the opening of the Settle and Carlisle line, which is a competing line with the Lancaster and Carlisle Railway, and gives the Midland an independent route to the north. The first Act for this line was obtained as far back as 1866, and three years later the Company applied to Parliament to be allowed to abandon it. The application was refused, and the Company was compelled to construct it in the interests of the public. Cases of this description are rare, but when they do occur, they point to the very significant fact that "compulsory powers" can cut both ways.

Seventy and a half miles is the total length of the line, and as may be imagined, from the character of the country through which it passes, it includes some very heavy engineering works. Of this kind are cuttings 70 feet in depth, and among other large embankments one of 100 feet in height. The breadth of ground required for the base of this bank, which settled and spread considerably during its progress, is something quite exceptional. Many of the bridges and viaducts are of unusual dimensions, and the foundations of some have been laid at a depth of nearly 60 feet below the ground line. The line is laid with rails 82 lbs. to the yard.

An extension of 21 miles in West Herefordshire possesses some importance. It effects a junction with the Hereford, Hay, Brecon, and Leominster Railways, and opens up direct communication with the coalfields and ironworks of South Wales. A branch of 10 miles directly connects the town of Leeds with Wetherby, and notwithstanding its comparative short length, it is crossed by no less than forty bridges over and under.

That the importance of the results accruing from the con-

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struction of a railway, is not to be measured by its mileage or cost, or the magnitude of the engineering work upon it, is shown by the opening of the new route between Bewdly and Kidderminster. It is only 3 miles in length, but it gives to the London and North-Western Railway the entrée into South Wales, and will save that Company several thousands of pounds per annum.

In the metropolis a branch has been made connecting the London, Chatham, and Dover Railway with the South-Eastern Railway, near the abandoned Blackfriars Station of the latter line. The Metropolitan has pushed its way from Bishopsgate to Aldgate. Among other works, this extension necessitated the undermining of the warehouses of the St. Katharine Docks Company. It was originally intended to carry this line to Tower Hill, and there to effect a junction with the Metropolitan District Railway. The intention was, however, abandoned, but the project will probably be carried out by an independent Company, who have obtained an Act for the purpose. The proposed line will now go by Fenchurch and King William Street. It is earnestly to be hoped, that one of the objects of the proposed line will be, at all events, carried out, and quickly too, namely, the widening of Fenchurch Street. In fact, the existing condition of Fenchurch Street, Fenchurch Railway Station, and the streets adjoining, is a standing disgrace to the City.

On the Continent, and abroad generally, no very prominent extensions have marked the last annual epoch of railways. Some fresh lines, of no great length, have been opened in France, Italy, Portugal, and Spain, and some progress has been made in the same direction in Algiers. In Hungary and Austria, the construction of railways has been nearly at a standstill. Brazil has shown some little activity with regard to her railway system, and has opened another section of the San Paulo and Rio Janeiro line. Australia has not been idle in promoting internal steam communication, and there will soon be an unbroken route from Sydney to Melbourne. About a couple of millions are to be expended in the construction of future lines, and for some months past measures have been taken to organize a staff of engineers to carry out the work. The Indian government is contemplating the construction of some new state lines, which will entail a considerable expenditure, especially in bridges and viaducts. There are also several irrigation projects to be carried out. The following facts will prove the influence exercised by railways, and public works in general, over the revenue of India. It was about 1852–53 that public works in that country were vigorously pushed on. At that time the total revenue of India was 27

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millions. In 1874-75 that sum had increased to nearly 51 millions, while in the same period the customs were nearly doubled. In the years 1875-76 about 12 millions were spent in engineering works generally. Of the total contemplated mileage of the state railways, amounting to 9400 miles, there remain 3000 yet to be constructed. In the three presidencies, taken together, there are over 800 civil engineers employed under the Indian government.

Japan has opened another section of line between Kioto and Osaka, and there is very little doubt but that the railway system of travelling has taken firm root in that country, and only requires time for its thorough development.

In addition to these examples at home and abroad there is one line, half of which has been recently opened for traffic, which promises a great future to the profession, if it should prove to be, as I trust it will, the precursor of others in the same country. I allude to the experimental railway, 10 miles in length, which has been introduced into China to connect Shanghae with Woosung. This was opened on the 30th June last, to Kangwang, a station situated about half-way between the present termini. The gauge of the line is 2′ 6″. The rails are of the Vignoles' pattern, weigh 27 lbs. to the yard, and are laid on cross sleepers. Engines of a particular class have been designed to work the line.

Great as are the advantages which would accrue from a general introduction of railways throughout the length and breadth of the Flowery Land, even if estimated solely by the demands and requirements of the lines themselves, they would be as nothing, compared to the results, subsequently attendant upon the establishment of steam locomotion throughout that vast empire. Railways always were, and are now, in the widest sense of the term, the avant-couriers of modern civilization, and in their wake inevitably follow all the material benefits which a country can possibly desire. Let the locomotive once run from the coast to the capital, and steamers would soon ply upon the rivers and lakes of China. Its industrial and mineral wealth would receive a stimulus to which they have hitherto been strangers. Factories and mills driven by steam would be speedily established in the central depôts of trade, and independently of the facilities provided for exporting the products of the more distant parts of the kingdom, an enormous development of its own internal commerce and traffic would eventually take place. Europeans would cease to be strangers in the land, and the people of China would no longer remain, as hitherto, a nation, isolated amongst

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nations. The advent of the Chinese Embassy at the present time is singularly fortunate, and it is to be hoped that the proper measures will be taken to bring this great question before them.

From railways, to accidents upon railways, the transition is, unfortunately, but too easy. The Radstock, Abbots Ripton, and Arlesey accidents upon our own lines, destructive to life as they were, sink into comparative insignificance, when contrasted with the appalling catastrophe which attended the fall of the bridge at Ashtabula, on the Lake Shore Railway in America. In the first three of these alone, twenty-nine lives were lost through preventable causes. At Radstock, on the Somerset and Dorset Railway, the collision occurred on a single line, as was the case in the well-known Thorpe accident. The line was under the immediate control of a crossing agent, and protected by the single needle block system. The calamity was attributed to the neglect of the one and the failure of the other. The primary cause of the double collision at Abbots Ripton, in which thirteen lives were lost, was the fouling of the line by a goods train, which was run into while in the act of shunting. Owing to the extreme inclemency of the weather, attended by a severe snow storm, the signals did not perform their duties properly. While matters were in this state, the Leeds express came along, and smashed into the two trains in front of it. Want of sufficient brake power prevented this last train from pulling up in time. The circumstances attending the Arlesey collision are too fresh in the memory of everyone to need recapitulation. They are very similar to those described in the former instance. Both Abbots Ripton and Arlesey are signal and shunting stations only. The cause in the latter case was the same, viz. the shunting of a goods train, with the additional evil of three waggons leaving the rails. Failure of the block system, and want of sufficient brake power, are the reasons assigned why the collision was not avoided. Judging from these instances, and bearing in mind that collisions are the most fruitful source of fatal accidents upon railroads, the inference to be drawn is, that prevention would be better than cure. The removal of the cause would be preferable to the adoption of expensive and extraordinary measures to avert the effect. It has been long foreseen, and this periodically occurring destruction of life and property must inevitably hasten the result, which is, that separate lines must be provided for the passenger and goods traffic.

The fusion of the South-Eastern with the London, Chatham, and Dover Railway, may probably afford the first practical illustration of the separation of the two descriptions of traffic, which

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may be conveniently termed the fast and the slow. The joint Company will possess so many duplicate lines to the same places, that it can readily devote one to the express and fast traffic, and the other to the slow, and thus test the relative safety and economy of the separate systems.

Having referred to the terrible disaster on the Lake Shore Railway at Ashtabula, it will be interesting to enter somewhat further into the cause of a calamity, which left only fifty-nine people alive, out of a total of 179. The scene of the accident was a bridge crossing a creek, having a span of 150 feet. The bridge was of wrought iron, and of the type known as Howe's truss, a very common form in use in America, especially in timber bridges. The train was drawn by two engines, and travelling very slowly. The bridge suddenly, in the words of one of the drivers, "snapped asunder" in the centre, and fell into the creek, the whole of the train falling with it, with the exception of the leading engine. It has been stated that some of the carriages left the metals, and the platform of the bridge was not strong enough to stand the shock. But it was not the cross beams or platform that solely gave way, but the main girders and all. A train might leave the track while crossing a bridge and break through the cross girders and platform, and yet the main girders remain intact. It is only in bridges of the tubular form, such as the Britannia bridge, that the failure of the cross beams and platform would, necessarily, cause the downfall of the structure. In bridges of that particular type the platform constitutes the lower boom, and there is no separation or distinct classification between the main girders and the cross girders.

It is difficult to believe that the bridge at Ashtabula could have been of the proper strength, although it is said to have been originally tested by the weight of six locomotives running over it together. Neither can the assertion that the ironwork was so much affected by the action of frost, as to become weakened to the extent displayed, be accepted as a satisfactory explanation. If that were true, engineers would have to renounce building iron structures in cold countries. This bridge was only eleven years old, and in strong contrast to its lamentable failure, after so ephemeral an existence, may be mentioned the fact, that about three months ago, a dinner was given at Bangor in Wales, to celebrate the 50th anniversary of the magnificent suspension bridge of Telford over the Menai Straits.

In connection with railways at home, two very important works have made considerable progress lately. I allude to the bridges over the Tay and the Severn. The former of these was

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commenced in 1871, and is intended to connect Dundee with the branch line of the North British Railroad between Edinburgh and Tayport. It has eighty-five spans, varying in dimensions, the greatest of which is 245 feet. The height at the centre is 88 feet above high-water mark. The piers are of brickwork, coped with stone, upon which are fixed cast-iron columns in groups of six to carry the girders. These are all of the lattice form with parallel flanges, with the exception of three at the centre, which are bowstring girders. Another year or two will probably witness the completion of this great work, which will have a total length of 10,321 feet, and will be the longest bridge in the world over a running stream.

The object of bridging the Severn is to connect the Great Western and the Severn and Wye Railways with the Midland. There are twenty-two spans, crossed by bowstring girders, of which the largest is 327 feet in length. One of these is a swing span, and there are twelve arches, 70 feet in height, forming the northern approach. Fifteen of the cylinders composing the piers are already in position, and eight spans of girders, and superstructure are completed.

In the course of last summer, the erection of the new Liteini bridge over the Neva at St. Petersburg was very energetically commenced. It is a wrought-iron structure, 1483 feet long, and is composed of seven spans, varying from 175 to 244 feet, with one swing-opening of 70 feet. The foundations will consist of wrought-iron caissons sunk, by the pneumatic process, to a depth of 42 feet below the bed of the river. The caissons will be filled with masonry, and the piers will have a total height of over 90 feet. The men will have to work under a pressure of from three to four atmospheres. Next autumn is the time specified for the bridge to be ready for traffic. A very fine bridge has been recently opened at Buda-Pest over the Danube. It is 1900 feet in length, and has a width of 56 feet.

The well-known suspension bridge of Mr. Tierney Clark, completed in 1849, is in the same locality, but the dimensions are considerably less than those of the new structure.

In America, bridge-building operations are still continued upon a large scale. As the trade of the country increases, facilities for communication and transport become every day more requisite. Moreover, the Americans have a long task before them, in the eventual substitution of iron structures for all those, which the necessities of a new country compel them to build, in the first instance, of timber. At Philadelphia the river Schuylkill is being spanned by a bridge 2000 feet in length, with a draw span. The roadway is 26 feet wide, and there are two

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footpaths, each 10 feet wide. Granite is the stone selected for the abutments, and the piers, which are thirteen in number, consist of cast-iron cylinders sunk until they reach a bed of rock. At New York the towers and anchorage of the Brooklyn bridge are completed. The principal cables will be composed of nineteen strands, and each strand will contain 330 wires. The works of the East river bridge, which were stopped for some time for want of funds, have been resumed with every prospect of a successful completion.

Notwithstanding the great length of the Tay bridge, it has been very closely approached by a similar structure in India, over the river Chenab. This bridge was opened by the Prince of Wales, during the recent tour of his Royal Highness in that country. It has sixty-four spans of 142 feet each, making a total length of one and three-quarter mile, and cost over half a million of money. Those of the members who attended an excursion of the Society two years ago, in which the Engineering Works of Messrs. Westwood and Baillie were visited, had an opportunity of inspecting the girders of the Chenab bridge, not only in course of construction, but also in a finished state. At the time of the visit, one whole span, with the cross girders complete, was rivetted together, in order to satisfy the Indian government of the condition and security of the work.

The ever-recurring question of the relief of the traffic over London Bridge, has been thoroughly well ventilated. A new bridge, or a subway lower down the stream, are the projects which meet with most favour. The plan of placing new footpaths outside the present parapets, and thus increasing the width of the roadway by the space they now occupy, in spite of being vigorously advocated, may be said to be definitely rejected. It has been gravely stated, that, in addition to the æsthetical disfigurement which the alteration would cause, the foundations would not carry the extra weight of the two new footpaths and the increased width of roadway. In the interest of art I concede the former of these statements, but as an engineer I dispute the latter. If the steam ferry at Wapping, with its twin boats, the 'Jessy May' and the 'Pearl,' should prove a success, the object sought with regard to London Bridge, will be partially accomplished. My own experience of subways is, that unless built upon a large scale, they are better avoided. I should always prefer a bridge, *cæteris paribus*, to a subway.

Some short time ago, a good deal of agitation prevailed respecting the dangers which pedestrians incur in crossing the streets, where the great arteries of our metropolitan traffic

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converge. These dangers are not exaggerated, and it has been seriously urged, with a great deal of common sense, that some means of passing over or under the crossings, should be provided. In plain language, either bridges must be erected or subways built. A subway of this character, unless it be perfectly straight from end to end, requires to be regularly patrolled, or it soon becomes nothing better than a common sewer. Anyone who entertains a doubt on this subject, can speedily dissipate it, by visiting the subway under the Blackfriars Station of the London, Chatham, and Dover Railway.

It is scarcely a fortnight since the President of the Society of Telegraphic Engineers delivered an admirable address, touching upon the salient points connected with that branch of the profession. I have therefore but one or two remarks to add. There can be very little doubt but that all inland telegraphic lines should be laid under ground, not merely for the sake of preventing the poles and wires being blown down and communication interrupted, as constantly occurs during severe weather, but also for strategical reasons. The Germans, who certainly possess the merit of appreciating and adopting all measures calculated to ensure efficiency and security, are protecting, and at the same time concealing, their inland cables in this manner. A very significant fact was made apparent by the interruption of direct telegraphic communication between this country and India. For a period of six weeks, during which time the Eastern line viâ Suez and Aden was not in working order, all messages had to be forwarded viâ Russia, Teheran, and the Persian Gulf cable. It is to be presumed that there are repeating stations along this route, and therefore it is very doubtful whether the privacy of the messages was ensured. In any case, it is not a pleasant prospect to contemplate, that in the event of our relations being unfriendly with either Russia or Persia, telegraphic communication between England and its chief oriental dependency might be suddenly interrupted for a considerable time. Submarine cables, although apparently out of danger from physical force, are not exempt from accidents. One of the Anglo-American cables has been broken for the last three years, and the direct United States cable has been damaged three times. The directors of the latter company have been so impressed with the idea, that the damage must have been done maliciously, that they offered a reward of 1000*l.* for the detection of the delinquent. As I have already made allusion to the first railway in China, I may remark that the first line of telegraph has been recently established in that country.

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The observations which I have made with regard to the completion of our great railway systems, do not apply to various other equally important works of construction, coming under the province of the engineer. Many extensive works in the shape of docks, harbours, piers, water supply, and sewerage of towns have been commenced, continued, and ended during the past year. Of these, one of the most prominent is the Victoria Dock extension, of which I have already spoken. It will save vessels a troublesome navigation through the Woolwich and Bugsby reaches of 3½ miles, by establishing a new entrance in Galleons Reach on the Thames. The length of the extension is 1¾ mile and the area 95 acres. The new dock will be 540 feet long and 27 feet deep below Trinity high-water mark, and the quay wall 9000 feet in length. The dimensions of the entrance lock will be 800 feet by 80 feet, and the depth of water at the cills, referred to the same datum, 30 feet.

New docks are also in progress at Milford Haven, Glasgow, and Greenock. At both of these latter places the works are of an important character, comprising in the former case a dock 1600 feet in length by 300 feet in breadth, with a tidal entrance leading to it 750 feet long by 70 feet broad. The depth of water at low-water mark is 18 feet, and the estimated cost 250,000*l*. At the latter port the length of wall and works is not far short of a mile. There will be nearly half a million cubic yards of excavation and 60,000 cubic yards of concrete. The tender was 207,000*l*. Whitehaven, Burntisland, and Newhaven have also made recent additions to their dock and harbour accommodation, and the Swansea authorities propose expending 30,000*l*. with the same object in view.

One of the most recent works in connection with hydraulic engineering, and also one of the most important in magnitude and commercial results, is the Amsterdam or North Sea canal, opened for traffic in November last. This may be justly considered as a national work, since it reduces the distance between the Port of Ymuiden and the North Sea by 36 miles. It comprises a canal, and a harbour in the North Sea. The harbour, designed by Sir John Hawkshaw, consists of two solid piers founded upon basaltic rock. The piers are built of concrete blocks from 4 to 10 tons in weight, and their dimensions may be imagined from the fact that there are in each pier 433,600 cubic yards of concrete, 77,700 tons of cement, 229,000 cubic yards of shingle, 130,900 cubic yards of basalt, and 19,035 cubic yards of broken bricks used in making the concrete blocks. Upwards of 300 vessels of large tonnage can find refuge in the harbour. The canal is 25,919 yards long, with

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a width at bottom of 88 feet 6 inches, and at top of 207 feet. The depth is 23 feet. The length of the branch canals equals that of the main channel, and there are 40 miles of dykes. There are 12,450 acres of land reclaimed along the sides of the canal, and the excavation amounted to 13,000,000 cubic yards. About 1300 yards from the western end of the canal, the docks are placed. They are provided with very high and strong gates, with extra ones to be used when the tide is very high. The larger dock admits a vessel 393 feet long and 59 feet wide, and has a depth of water over sill at ordinary low water of nearly 29 feet. At the other extremity of the canal there are three docks, called the Orange Docks, the largest of which will admit vessels 315 feet in length and 59 feet in breadth, and the two smaller, vessels 239 feet by 46. There were 8870 piles used in the foundations of these docks and 27 pairs of gates in all. Of those 11 are of iron and 16 of timber. The cost of this extensive project was 2,000,000*l.*, and although its length is not so great as that of the Suez Canal, the engineering works connected with it are upon a larger scale. It may in every respect fairly vie with the latter enterprise, though it may lack some of the prestige which attaches to the Suez Canal.

While on the subject of docks, I should not omit to mention that one, on the floating principle, has been shipped to Russia and will be completed early in the present year. In it can be shipped an ordinary ironclad, and the circular vessels or Popoffkas. The dock is also divisible into three distinct portions, in each of which a gunboat can be docked. In British Columbia, the requirements of commerce have necessitated the commencement of the first graving dock in that territory. Among contemplated hydraulic works is the projected Rohne Canal, for which the surveys have been long since made. Four years would be occupied in carrying this project into execution. The canal would run through a district infested by the phyloxera, from which the vines suffer great loss. It would have the effect of removing this scourge, and also of preventing the disease in silkworms, which is very prevalent in the same locality. A ship canal is to be made to connect Lake Erie with Lake Ontario, and the project has been very seriously entertained of constructing a similar work to convert Manchester into a port.

The supply of pure wholesome water to a town, is one of the first considerations which should occupy the attention of the local sanitary authorities, and there is probably no professional duty, which taxes more the skill and ability of the engineer, than the designing and construction of waterworks. Un-

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fortunately but very few of our large towns are provided with this indispensable requisite to the health of the inhabitants, and when our examination extends to our smaller towns and villages, the result is unsatisfactory in the extreme. Not one in a hundred has any water supply in the proper sense of the term, and the unfortunate people have to obtain whatever quantity they can, from wells but too frequently sunk in close contiguity to the cesspool. The facts which have been recounted by the various royal commissions appointed to inquire into this matter, would not be credited, but for the unimpeachable evidence upon which they rest. At present, considerable agitation is going on with respect to the quantity, quality, and mode of supply of water to the metropolis. Whatever difference of opinion may exist with respect to two of these items, there is but one regarding the third. The quality of the water supplied by some of the companies to London is much below the proper standard of purity.

The case of Richmond presents some very unusual features in relation to the water supply of an important town. The ordinary water supply was cut off by the company, and the local authorities were obliged to have recourse to extraordinary means to provide the inhabitants with water. This is a state of affairs which the Legislature should not permit. No water company should be allowed to cut off the supply of water to a town, any more than a gas company should be allowed to plunge a town in darkness, by discontinuing the gas. Water and gas are as essential to the well-being and comfort of the people of large towns, as natural light and air. The following singular circumstance occurred the other day at Richmond. Two steam fire-engines were employed night and day to maintain a supply of water to the town. At the same moment in the immediate neighbourhood, at Kew, a similar amount of steam power was equally energetically at work, pumping out water from the hot-houses and gardens, to prevent the fires being extinguished.

The people of Richmond might well exclaim, like Coleridge's ancient mariner:—

> "Water, water everywhere!
> And not a drop to drink."

The opening of the Holme Valley Waterworks was successfully performed toward the latter end of last year. The cost was about 80,000*l.*, and the establishment of these works will be of the greatest benefit to the district.

Brighton was also provided with a further supply, by a

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method which I may briefly mention. The system adopted was to sink a number of shafts, and from them to drive a series of tunnels or headings into the chalk, and in this manner tap, or intercept, the water in its progress of downward infiltration to the sea.

During the ensuing year, it is intended to construct a new reservoir and other works at Bradford, at an estimated outlay of nearly a quarter of a million, and similar hydraulic works upon a minor scale will be actively commenced in many parts of the country.

Turning our attention to foreign countries, we find the authorities of Rio Janeiro are prepared to expend over a million in supplying the town with water; and it is satisfactory to note that a very large order for pipes has been taken by a firm in this country. Recently an expenditure of 100,000*l.* has been sanctioned for the construction of waterworks at Simla.

Irrigation works on a very extensive scale are projected on the Continent and in India.

In the latter country there are four principal descriptions of irrigation works: 1st. Inundation Canals. Examples of this kind are common in Sind and parts of the Punjaub. 2nd. Irrigation canals, whose waters are taken from rivers. These are principally in use in Northern India. 3rd. Canals in the deltaic portions of rivers; and, 4th. Tank irrigation. It is only by multiplying these several systems of irrigation throughout a great portion of Hindostan, that the severe famines which occur almost annually can be prevented.

The barrage of the Nile, the drainage of Lake Fucino, a work commenced twenty-two years ago and just completed, together with similar works in progress at Ferrara, are well worth the notice of engineers. At this last-mentioned place, the largest pumping engines ever constructed are almost continually at work.

A very useful application of hydraulic power has been recently made at Kingston-upon-Hull. A system of main pipes 6 inches in diameter is laid, for about a mile, along the docks, and charged by pumping engines with a pressure of 600 lbs. to the square inch. Any machinery, such as cranes, winches, or elevators, can be easily and economically worked, by simply connecting with the main pipe. The power required is close at hand, and a person can pay for the amount he wants and no more. Many advantages result from this arrangement to the users of motive power. First cost is avoided in engines and plant. Less space is needed, and consequently less rent of premises incurred, and the risk from fire is also very much diminished.

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It is with regret that I have to observe that we have not yet attained to a satisfactory solution of the sewage problem. There can be very little doubt that, so far as a principle is concerned, that of irrigation has given the only really reliable results. The number of different companies which have tried disinfecting and deodorizing processes, together with the manufacture of so-called artificial manures, is legion, and their numbers are equalled only by their failures. It has been calculated that one company alone squandered a million of money in the vain attempt to accomplish what, to all these processes, is a double impossibility, viz. the purification of the effluent water to the degree prescribed by the standard, and the manufacture of an artificial manure, which shall pay the cost of its own production. Irrigation, and irrigation alone, by calling nature to its assistance, effects the double result by a single operation. Unquestionably, the great drawback to the more general adoption of the irrigation system, is the difficulty of procuring land suitable for the purpose. At home, we are now tolerably familiar with the benefits which sewage irrigation confers upon every description of crop to which it is applied, and to the especial advantages which some particular crops derive from its application. The most recent successful example which has attended the adoption of the principle abroad is at Dantzig, a town the drainage of which was carried out by one of our past presidents, Mr. Baldwin Latham. The crops which have been produced, both in variety, number and quality, vie with those grown at the Lodge Farm, and on other well-known sewage farms in England.

The difficulty of obtaining land for irrigation purposes would be greatly lessened, if the powers conferred upon local boards were more vigorously supported and enforced by the higher authorities. That land still can be obtained is evident, if other instances were wanting, by the completion of the sewerage works at Oxford, where 350 acres have been acquired for the disposal and utilization of sewage by irrigation. Towns situated on the sea will doubtless continue to make use of that natural receptacle for their sewage, and it must be acknowledged that, in the matter of wasting so valuable a commodity, the metropolis sets them an example on a gigantic scale.

The dilemma in which local boards sometimes find themselves, with regard to the disposal of the sewage of their towns, is well illustrated by the case of the sanitary authorities of Kingston. The sewage of this town originally flowed, as was the universal custom in all places similarly situated, into the nearest river, which in this instance was the Thames. The

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Board of Conservancy gave the Kingston Board notice to discontinue this practice, under penalty of an injunction being obtained against them, after the lapse of a certain time. The answer of the Kingston authorities was: "You have closed the only outlet we have for the sewage and drainage of the town. What are we to do with it? Will you tell us where to put it?" The reply of the Conservators of the river was: "That is no business of ours. All we have to do, is to see that you do not discharge it into the Thames." In instances of this kind, of which this is not a solitary example, it would sometimes be difficult to draw the line of demarcation between real inability to comply with the legal order, and a plea which might be simply *in contumaciam*, and intended as an excuse for shirking the whole subsequent responsibility and expenditure. In the Kingston case, whatever might have been the validity of the plea for non-compliance, the injunction was obtained, and the penalties actually incurred for neglect gradually reached the sum of 10,000*l*. This modest total being arrived at, another respite was granted to the authorities to enable them to extricate themselves from their embarrassment. A comprehensive scheme of drainage, which embraces several towns and districts in the valley of the Thames, has since been proposed, and is at present under consideration. It is not, however, very creditable to our sanitary legislation, that injunctions affecting the health of the population should be systematically disregarded, and penalties of a fabulous amount, so far as any chance of their recovery is concerned, incurred with equal carelessness and indifference. In order to ensure the due enforcement of our sanitary rules and regulations, the hands of both the administrative and executive departments require to be strengthened.

The erection of gasworks in towns of any pretensions to size, either at home or abroad, is now so usual a procedure that it fails to excite much notice. New gasworks, or extension of existing ones, are being carried out in our own, as well as in nearly every foreign country which can lay claim to even partial civilization. The experiences of the last few years will clearly show, so far as the metropolis is concerned, that the tendency to amalgamation, or centralization, is very much on the increase.

In 1869 there were thirteen gas companies supplying London. In 1870 the number had diminished to eleven, not by the extinction of the other two, but by the incorporation or absorption of them into the others. This number was again reduced in the following year to ten, subsequently to

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nine, and ultimately to six, which represents the number of separate and distinct companies supplying gas to the metropolis. These are the Gas Light and Coke Company, the Phœnix, the London, the Commercial, the South Metropolitan, and the Surrey Consumers. The capital of these six companies in 1875 was over eight millions. One of the advantages attending amalgamation is, that a marked decrease has taken place in the loss of gas from leakage and other causes. The amount of loss has been reduced from 17½ per cent. to less than 7 per cent. But the chief benefit resulting from amalgamation is the diminished price at which the public can be supplied. Companies are empowered now to pay ¼ per cent. over and above the maximum dividend of 10 per cent. for every penny they take off the price of their gas per thousand feet. The companies supplying the metropolis with three-quarters of all its gas, now charge 3*s.* 6*d.*, instead of 3*s.* 9*d.*, per thousand, which is equivalent to ¾ per cent. more dividend. The quantity of gas sold by the companies who have made the authorized reduction, amounts yearly to fourteen thousand million cubic feet, which, taking the difference of the two prices already mentioned, benefits the consumers to the extent of 175,000*l.* per annum. It is an open question how far the principle of amalgamation will be carried. The companies situated respectively north and south of the river might amalgamate, or the incorporation of the whole, say into one, might be accomplished. It is very possible that the principle of incorporation will be carried still farther, but the advisability of its reaching so extreme a point as unity, is a fair matter for discussion.

The battle between guns and targets still continues, and any success on one side only calls for renewed opposition on the other. The penetrating powers of the one and resisting powers of the other appear to increase *pari passu*, and it is impossible, at the present juncture, to venture a surmise at what point the reciprocal powers of attack and defence will terminate. Our own 80-ton gun has been surpassed in point of weight by the 100-ton gun intended for the navy of the Italian Government, who has had two vessels specially constructed to carry these tremendous weapons. Our coming gun is to weigh 120 or 130 tons.

The ships of the Italian nation are intended to carry plates of enormous thickness. At Messrs. Cammel's works, at Sheffield, plates have been rolled for Italy 22 inches in thickness, to be shot at by the 100-ton gun. One of these plates measured 18 feet in length, 5 feet in width, and weighed 35 tons. A still thicker plate than this has been rolled success-

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fully at the Atlas Works. The thickness of this plate, which was perfectly sound and homogeneous, was 24 inches.

When the weight of any material becomes excessive, in proportion to its strength or resistance, the object at once sought for, is another material, or variety of the same material, which, with a given weight, shall form a greater power of resistance. This leads us to the consideration of steel, a material which, I believe, will ultimately play a most important part in all engineering works of a mechanical and constructive character. At present six steel gunboats are being built on the Tyne, and six steel-plated corvettes are in course of construction on the Clyde. What influence the use of steel may have on the speed of a ship of large size, remains to be seen, but if we may judge from a small example, it certainly does not diminish that important quality in a vessel. By a small example, I mean the 'Gitana,' a steel launch constructed by Messrs. Thornycroft, of which a few words may be said. The 'Gitana' is 91 feet long by 13 feet 6 inches beam, and is rigged as a fore-and-aft schooner. The engines are of the high-pressure condensing type. The boilers are of Bessemer steel, with copper fire-box and brass tubes, and work up to a pressure of 100 lbs. At her trial trip, this little vessel attained a speed of twenty-four miles per hour.

The substitution of steel for iron rails is a matter of considerable importance, and is fast becoming universal. Steel rails can now be bought at the same price as iron ones, and will last five times as long. If the ordinary Cleveland ore could be converted into steel, as there appears some prospect of, the whole iron trade in that district would be completely revolutionized.

In presenting to you the above brief notice of the chief points of interest to engineers, which mark the chronicle of 1876, my chief object, gentlemen, has been to draw your attention to the great range and scope of the engineering profession. It may be asserted, without any reference of an invidious nature, that the profession of an engineer has a far wider field for action, and embraces a more comprehensive grasp of natural objects, than any other. The engineer has comparatively but little to do with individuals. He deals principally with the great physical forces of the universe, and with such artificial agents and motive powers as the invention and ingenuity of himself or his fellow-men may have called into existence. He has to control and direct the inexhaustible sources in nature for the use, comfort, convenience, and welfare of mankind. Trade and commerce are mainly dependent upon his exertions, and

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the modern mode of communication, internal and external, is essentially his own creation. The most cursory glance at the results of the recent gales and inundations, to which I shall more particularly refer, will demonstrate the almost irresistible agencies with which he has to contend, and proves that many of his most laborious works are incessantly engaged in all the risks and dangers of elemental warfare. By profession, as by nature, an engineer is a cosmopolitan—distance, locality, climate, are all matters of perfect indifference to him. I mean no reflection upon the credit due to our brave explorers in the Tropics and the Arctic regions; but I venture to assert, that if a company were formed to make a railway to the North Pole, or through the centre of Africa, there would be little or no difficulty in obtaining a staff of engineers, who would undertake to carry out the enterprise.

I intended to make a few remarks respecting the somewhat ambiguous position in which an engineer is placed with regard to a recognized professional status, in comparison with the members of other learned professions. I have been given to understand, however, that it is the intention of the highest authority in such matters, namely, the Institution of Civil Engineers, to take some speedy measures for satisfactorily removing this cause of complaint—a cause which has existed a great deal too long. Whatever means may be adopted to prescribe some standard, some rubicon, which outsiders are not to pass, it is to be hoped it will be one which will place the profession upon an honourable, secure, and unmistakable basis.

One has heard very frequently of the apathy and tacit, unresisting submission of the mild Hindoo, and the general indolence which constitutes the chief feature of the Oriental disposition, when brought face to face with the destructive forces of nature. It would seem, if we are to judge from the experience of some years, that there is considerable danger of this lethargic temperament, this blind devotion to the doctrine of fatalism, taking root amongst ourselves. It is difficult, otherwise, to account for the utter indifference and culpable neglect with which, year after year, we have regarded the terrible devastations committed by storms and inundations. There may be some excuse for our Eastern neighbours and subjects. Even if they had the will, if they were endowed with sufficient natural energy to struggle against calamities of this kind, they certainly do not, in many instances, possess the means. We cannot claim to be excused upon this score, as we unquestionably possess the means. We have at our command ample professional ability for the proper designing and superintendence of the necessary works. There are many contractors, men

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of the Brassey type, who never see obstacles until they are overcome, who would be willing to undertake the erection of the works. The adequate funds could be obtained from many sources. They have been found, and, moreover, found to superfluity, for the relief of sufferers from these very causes which it is now proposed to avert. Besides voluntary contributions, there would be the rates and taxes, and payments from those whose property would be protected from future damage, and, in case of necessity, the aid of Government, in the shape of loans, would not be wanting for the ultimate prevention of what is annually becoming a great national disaster.

The accounts of the recent gales and floods show that in some instances the damage done is shared pretty equally between them, but as a rule the injury resulting from the former is more conspicuous along our sea-coast, while the influence of the latter is principally felt in the interior of the country. Again, the violence of the gales is the cause of two-fold mischief. First, on the sea, and, secondly, on the shore. It may be said that we cannot prevent storms, and the loss which occurs in consequence to life and shipping. True, but we can provide our shores with some more frequent and adequate shelter and protection than what exists at present. The unsheltered condition of our coast is a standing disgrace to us, as an essentially maritime people, and the first naval power in the world. It is notorious that the seaman dreads the coasts infinitely more than the open sea, and it is but too well known that, owing to the same cause, thousands of our fishing and sea-going population earn bread for themselves and their families at the daily jeopardy of their lives. The total number of harbours in the United Kingdom is not a tenth of what it ought to be. Of these, many are useless, owing to silting up and other causes, and completely unapproachable except by craft of very small dimensions. Others can only be entered at certain states of the tide, and during certain directions of the wind.

There cannot be the slightest doubt that, so far, the insuperable obstacle to the construction of harbours and breakwaters has been their enormous cost. There are also many localities, where they are urgently needed, in which it would be well-nigh impracticable to build them according to the plan usually employed. Those considerations will naturally lead to the reflection, whether it might not be possible to design harbours and breakwaters, differing, both in design and the material employed, from the stereotyped solid structures hitherto adopted.

Some six years ago, I read a paper on "Floating Break-

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waters" before this Society, for which it did me the honour to award me a premium. In that paper I advocated the floating principle for the construction of harbours and breakwaters, which it would be out of place to further allude to at present. Since that time I have carried out experiments in the sea with large timber sections of the proposed form of breakwater, and the result has been to confirm the opinions I then held, and to encourage me in the belief that the principle, which possesses the great merits of safety and economy, may yet become of practical use, and afford in similar stormy weather to what we are now experiencing, access to the shore, shelter to the shipping, and safety to the sailor.

The damage done to sea walls, marine promenades, jetties and piers by the late storms, is something quite unprecedented, and has not been confined, as is more frequently the case, to any particular part of the coast, but has extended nearly entirely round our seaboard. While the piers at Brighton and Hastings have suffered but slight injury, that at Eastbourne has been broken in half, and a large portion of it carried away. Similar structures have suffered severely in other localities, and the massive stones of the Dover harbour were not proof against the transporting and impactive fury of the waves. At Macduff, a pier, which had long been in a very insecure condition, was partially swept away, while the piers at Saltburn-by-the-Sea, Redcar and Coatham on the Yorkshire coast, were all more or less damaged. The cost of repairing the injury sustained by the last mentioned of these is estimated at 3000*l*. Two hundred yards at the far end were destroyed, together with a lighthouse. I have a pier at present in course of construction on the same coast, and I think I am very fortunate in being able to state that hitherto it has suffered no damage worth mentioning. At Blackpool the pier has been considerably injured, and the force of the gales has been severely felt at Lytham and other parts of Lancashire. The latest example is the fall of the two large girders, 245 feet span, of the Tay bridge.

Serious as the losses appear which are due to the cause just discussed, they are not so widely spread as those resulting from unchecked floods and inundations. It is discreditable to the nation, and a reproach to engineers, that our rivers and streams are not kept in better subjection, but are allowed to be masters, instead of good and useful servants. We have witnessed the traffic on our roads and railways interrupted, bridges and tunnels destroyed, mines flooded, mills stopped, houses swept away or rendered uninhabitable, hundreds of

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people thrown out of employment, and thousands upon thousands of acres of land submerged, and rendered, for the time being, useless for the purpose of tillage and agriculture. In one county alone, it has been calculated that over 25,000 acres were inundated, and that the damage to property of every description was over a quarter of a million. What is required, to remedy for once and all, disasters of this kind, is union and action.

It was asserted, perhaps with more indignation than judgment, that the embankment of the metropolitan portion of the Thames was the cause of the serious floods which occurred in the low-lying parts of London contiguous to the river. This is not correct; but it must be borne in mind, especially with reference to the future prevention of floods upon a large scale, which I am now considering, that the partial embankment of a river may do more harm than good. It is for this very reason, that the isolated efforts of one or two riparian proprietors will be of no avail in averting the effects of future inundations. The majority of our rivers require not merely to be embanked in various parts of their course, but to be widened in some and narrowed and straightened in others. It is nevertheless a mistake to suppose that taking the bend out of a particular part of a river is always an improvement. On the contrary, it frequently increases the tendency to scour, which may be very injurious to places lower down the stream. There can be no question but that the embankment of the Thames from Blackfriars to Chelsea has increased the scour of the stream, a contingency which was very probably not taken into consideration when Waterloo, Southwark, and London Bridges were built.

The destructive action of rivers has been one of the greatest difficulties which the engineer in India has to contend against. Lately, the works on the Madras line have been very seriously injured for a distance of over a hundred miles, and the failure of the Nerbudda bridge will entail its reconstruction, at a cost of over a quarter of a million. This structure was erected on screw piles, a method which is to be abandoned in the building of the new bridge, which is to be supported on cylinders. Many years ago, when railways in India were in their infancy, a good deal of discussion was carried on respecting the most economical length of span, or ratio of superstructure to foundations. The conclusion arrived at was theoretically correct; but if we consider that real economy lies in the durability of the work, practice has not borne out this conclusion. The capricious character of the Indian rivers is such as to defy all calculation and precedent.

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They not only frequently change their course without any apparent reason, but have been known in a single night to scour out their channels to a depth of more than thirty feet. Under these circumstances, it is obvious that the less they are interfered with, the better, and the fewer the number of obstructions, in the shape of piers, opposed to their current, the safer will be the bridge spanning their waters. Evidently, the perfection of a bridge in such a situation would be one which reached from shore to shore. It would not always be possible to accomplish this result; but by the use of large spans, I mean very large spans, the desired end might be, in many instances, very closely approached.

In speaking of the employment of steel, I had this consideration before me. A wrought-iron bridge could not be constructed of a greater single span than 700 feet, and even when of that dimension, the iron would have to be of an exceedingly good quality in order to bear a high unit strain. I exclude from this category all bridges belonging to the suspension principle, as hitherto experience has failed to prove that they can be made suited for railway traffic. By railway traffic, I do not mean the mere transit of the train across, with or without the engine, at a snail's pace, but the passage of an express running at the rate of the Irish mail or Flying Dutchman. No suspension bridge yet constructed would stand this test, and it is very doubtful if any on that principle ever will. If steel, in large quantities, could be procured of a thoroughly reliable quality with regard to the high compressive and tensile strains which specimens have shown it to possess, bridges and other structures could readily be built of far larger dimensions than at present, and smaller examples would cost relatively much less. By the use of steel, spans of 1200 feet might be reached, without approaching too near the limit, and a very few of these would carry a bridge over the largest of the Indian rivers.

The relations between capital and labour continue, it is to be regretted, still in a very unsatisfactory condition, and the sooner some solution of the difficulty is arrived at, the better it will be for all parties concerned. I do not agree with those who adopt extreme views, and prophesy, in consequence of the unsettled condition of the relations between employers and employés, the ultimate ruin of our trade and commerce; but I do think that no reflecting man can regard, without feelings of disquiet and solicitude, the aspect which this very important question has for a long time assumed. One fact ought not to be omitted in connection with this matter, upon which I shall

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not make any comment. The Shirland Colliery, in Derbyshire, was purchased some time ago by a miners' association, in order to carry out the principle of co-operation. It has since been sold, and the association has lost over 30,000*l.* of the amount originally subscribed in shares by the members. One of our leading journals remarks, "The experiment of co-operation has thus ended most disastrously." A co-operation cotton factory established in Liverpool met with a similar fate. Union, whether between masters or between men, is always to be desired, but the union must be kept within proper bounds, and intolerance and coercion must form no part of the compact.

In conclusion, I wish to address a few words to those who intend to adopt the profession of an engineer. I do not mean to indicate any particular course of training to be adopted. There are abundance of good schools and colleges, where the young man can receive a sound preliminary education, previously to entering upon the technical part of his career. Moreover, the early portion of his training must, in a great measure, depend upon the means at his disposal. It is not everyone who can afford, either the time or the outlay, to spend from three to four years at a university. There are one or two stumbling-blocks which are to be sedulously avoided by anyone who intends to be an engineer. In the first place, bear in mind that the profession is essentially a practical, although a scientific, one, and that a knowledge of its duties, and the qualifications necessary to constitute an engineer, are not to be learned from books alone. Theory, without practice, is of little or no use. For the mechanical engineer the office and the workshops, and for the civil engineer the office and actual residence on works of construction, are the only passports for those who aspire to be admitted on an equality among their professional brethren. In the second place, let the young engineer enter the profession by the door, and not by the window. The days of "rule of thumb" are gone by, never to return, and the avenues to the profession are more stringently guarded than in past times. Admittance to our own Society, as well as to others of a professional character, is only permitted under certain conditions; the first of which, for full membership, is that candidates must be, or must have been, *bonâ fide* engaged in professional works.

I would also offer a word of advice to those who have passed the threshold, and are entering into active employment. Let them not expect to jump into a thousand a year at the expiration of their articles. At the same time, look before you. Be earnest and zealous in the discharge of your duties; upright,

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manly, and conscientious in your conduct. Be not dissatisfied with your present condition, whatever it may be; but do not neglect to qualify yourself for the duties of a higher position. Be ready, without being over eager, to take advantage of the chance of promotion; and, in aspiring to obtain honour and reputation in your profession, bear in mind the words of the American poet—

"Lives of great men all remind us
We may make our lives sublime,
And departing, leave behind us
Footprints on the sands of time."

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March 5th, 1877.

THOMAS CARGILL, PRESIDENT, IN THE CHAIR.

THE MECHANICAL FIRING OF STEAM BOILERS.

By J. WALTER PEARSE.

THE many disadvantages of hand stoking, even when performed by a careful and experienced man, are only too apparent. The supply is intermittent and therefore irregular. However evenly and lightly the coal may be distributed, combustion must be imperfect, and must therefore favour the escape up the stack of unconsumed gases. The opening of the fire-hole door admits a volume of cold air on to the top of the fire, which not only increases the last-named evil, but also further creates waste by lowering the temperature of the flue. In addition to this, the hard physical labour of firing has to be performed under exposure to the direct heat of the furnace. If approximately regular firing is difficult to ensure on land, it becomes still more difficult on board ship, especially during heavy weather, when keeping steam is perhaps of the utmost importance.

The advisability of superseding uncertain and irregular manual firing by a continuous feed, effected by mechanical means, was felt at the beginning of the present century; or, at any rate, this appears to have been the period when projects for mechanical stoking first assumed a practical form. Reference to the latter portion of a paper "On the Use of Coal in Furnaces without Smoke," read before the Society on the 12th of May, 1862, by Mr. Charles F. T. Young, will show that brains were busy as early as 1813 in endeavouring to solve this important problem; and a search into the records of the Patent Office affords evidence that many patents were obtained for accomplishing this object in one form or another, even if that form were somewhat clumsy when compared with the more perfect machines in use at the present day.

The author of the present paper does not attempt to trace the history of mechanical stoking from the beginning of the

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century until now, but will only describe such appliances as have attained a certain amount of practical application, dwelling at greater length on those stokers which are at present doing good service in lessening the consumption of fuel, preventing smoke, and substituting power for manual labour in a field where such a change is highly desirable. In most of the appliances, some automatic arrangement for stirring the fire, cleansing the bars, and removing ashes and clinker, accompanies that for the supply of fuel. Indeed, the two go hand in hand together; for it is evident that but half the desired advantage is obtained if, while a man is saved from the labour of throwing coal on the fire-grate, he is still exposed to the fierce heat while raking the bars, and if the fire-door, kept carefully closed against the admission of a supply, be opened for the discharge of the waste matter, with all the attendant evil of the in-rush of cold air.

In the year 1822 Mr. John Stanley invented a stoker with a pair of fluted horizontal rollers for crushing the coal as it descended from a hopper in front of the boiler, at the same time equalizing the supply. Below the rollers was fixed a three-armed fan, revolving on a horizontal axis, for projecting the coal into the furnace. In 1834 Mr. Stanley, with the co-operation of Mr. John Walmsley, substituted indented rollers for fluted, and made his fan to revolve on a vertical instead of a horizontal axis. He also arranged the fire-bars so as to rock by means of gear connected with the stoker, and caused the steam in the boiler to act on a float in a syphon tube for stopping the feed when a certain pressure was attained. In 1838 Mr. John Juckes patented an arrangement of screw rams, by which successive charges of fuel were forced into tubes, where the coal was distilled before being discharged into the furnace. In 1839 he devised a narrow movable platform in the middle of the fire-bars, and hinged at the back end. On a fresh charge being propelled by a plunger on to this platform, it was forced up on a level with the fire-bars, both actions being performed by levers. In 1841 Mr. Juckes patented the invention with which his name is more particularly associated, viz. an endless chain of fire-bars, supported at each end by rollers, which are carried on trucks. As the chain passes under the boiler, it draws from a hopper its supply of coal, which is regulated by a door sliding vertically. In the next year Mr. Juckes somewhat modified this idea in the construction of his circular grate, made to revolve by means of a rack fixed to the circumference, and actuated by a pinion. A portion of the grate is always outside the furnace, when the bars, which are

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pivoted at one end, fall down in succession to allow of the disengagement of clinker, and are then raised again before entering the furnace. The fuel is drawn along much in the same way as in the previous arrangement.

In 1863 Messrs. Wilson and Smith caused their fire-bars, which were of the ordinary shape or nearly so, to travel backwards from the front of the furnace, so as to carry towards the bridge the fuel fed from a hopper provided with a regulating damper; the bars then moved backwards, either singly or in pairs, the motions being given by two drums, fitted with projecting arms, placed underneath the bars at the front end, and driven by any suitable means.

In 1867 Mr. Thomas Vicars, Mr. Thomas Vicars, jun., and the same Mr. Smith, patented some improvements on the preceding invention. Between the Wilson and Smith fire-bars they placed others of shorter length, moving backwards and forwards to a less extent than the travel of the former, from which they received motion. Again, instead of passing all the fuel from the front end under the furnace door, they supplied the whole or part of it from a hopper, situated at a higher level, and from which tubes descended to the grate. In some cases part of the supply was led by a tube through the boiler itself, so as to deliver about midway between the front end and the bridge.

In 1870 Mr. Dillwyn Smith filed his specification. In the stoker associated with his name the coal is allowed to fall from a hopper in front of the boiler into a horizontal cylindrical receptacle, in which works a helical screw for giving the feed. In the case of a double-flued boiler, the screw is made right and left handed, the middle being placed just under the centre of the hopper; and from the middle the diameter of the screw gradually increases until, at the ends, it becomes almost as large as that of the casing. At the ends of the screw-shaft and outside the screw, are projections for more evenly distributing the coal as delivered by the screw. The pieces of coal are caught in falling by the vanes of a pair of fans, revolving towards each other in a horizontal plane, and are by them projected on to the furnace. As the pieces which are struck by the ends of the vanes are projected farthest into the furnace for a given size, and as the size of the pieces varies, it follows that an even distribution of fuel is effected over the whole area. The fan-shafts are driven by belts from a separate vertical shaft, actuated by a donkey engine or any available power; and the shaft of the feed-screw is driven by a worm and worm-wheel put in motion by another vertical shaft worked by a

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strap off one of the fan-shafts, a pair of cone pulleys and a rod and lever serving to change the speed as may be required. A large number of stokers have been made on this plan, and many are still at work, giving admirable results as regards the saving of fuel. Mr. Dillwyn Smith also included in his patent an arrangement of two separate fire-grates in one flue, with argand fire-bars in the centre, so contrived that the gases distilled from the coal on the former are burnt with perfect combustion by the heated air proceeding from the latter. The grate-bars are placed across the flue, and are made to move from time to time by the turning of an octagonal shaft on which they rest.

In the same year (1870) some improvements on the Dillwyn Smith stoker were made by Mr. George Frederick Deacon. It sometimes happened that when large coal was used some of the pieces were not sufficiently reduced by the screw in one of their rectangular directions. To obviate this, a second but smaller thread was introduced between the main thread, and, like it, gradually increasing in diameter. It was also found that coal dust sometimes accumulated between the disc of the fan and the bottom of the casing; this was counteracted by casting a narrow spiral feather on the bottom of the disc, and making some holes to admit the air, so that a sufficient draught was created to prevent the accumulation. At the same time, the fan shafts were reduced in height, chiefly for lessening the friction on the lower foot-step, which for this reason, as well as on account of the conducted heat from the furnaces, it was sometimes found difficult to keep cool. A non-conducting substance was also introduced between the foot-step and the underside of the fan-case. One of the fan-shafts was, however, retained at its former height to serve for driving the others, the pulleys of which were kept as near the fans as the screw casing permitted. Each of the shafts had two bearings in a single bracket above the fan; and the step was sometimes dispensed with altogether by forming a collar on the upper ends of the shafts. Subsequently the fan-shafts were driven by toothed or friction wheels, enclosed in a chamber immediately below the fan-case, thus dispensing with all but one belt, because the latter were found to be deteriorated by the heat of the fire if the machine was kept standing for any length of time. Perhaps the most important addition made by Mr. Deacon was his deflector for causing all the particles of fuel delivered by the screw to fall upon the fans. This consists of two castings bolted together, shown in elevation at Fig. 1 and in plan at Fig. 2, where A is the aperture through which the fuel

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falls, and F F the two fans. The particles are prevented from falling between the fans on the hinder side of their centre line by the inclined edge E of the plate D, and at the front side by the part B, which has a triangular section and curved base. The handle H, the stud of which passes through the slot S in the fan casing C, allows the deflector to be moved both inwards and outwards as well as in a radial direction, until that position is found in which the most uniform delivery is secured.

The Henderson stoker, which incorporated Mr. Deacon's additions, contains still further improvements on that invented by Mr. Dillwyn Smith; and the two interests are now merged in the Mechanical Stoker Company. Additions and modifications were patented by Mr. Thomas Henderson in 1872, 1874, 1875, and so late as the end of last year. Instead, however, of following these successive changes one by one, it will perhaps be better to describe the Henderson stoker as it now exists with the latest improvements introduced.

Fig. 3 shows a front elevation of the stoker as applied to a Lancashire boiler; Fig. 4 is a side view, partially in section; and Fig. 5 a horizontal section, showing the fire-bars. The coal contained in the hopper A is fed down the two divisions, one in front of each flue, by means of a roller, which is modified in form according as it has to crush coal, or merely regulate the supply of slack. The particles are caught as they fall by the arms of two fans contained in the fan-case C, revolving towards each other in a horizontal plane, and are by them projected into the furnace, being distributed equally over the whole surface as in the Dillwyn Smith arrangement. The great improvement consists in the compact arrangement of parts, and the direct manner in which they are driven. Thus a horizontal shaft B, made to revolve by a belt and pulleys, or in any other convenient manner, is carried by bearings immediately under the fan-case, and, by means of a worm in the centre, turns a worm-wheel D on a nearly vertical shaft E. This shaft carries a worm at its upper end, which gears with a worm-wheel F, keyed on the feed-shaft, while it has another worm at its lower end for moving the fire-bars. The fans are driven direct by friction pulleys G G, on the horizontal shaft, working against a ring of leather, for preventing rattle, fixed to their hollow under side. The fans, therefore, revolve at the rate they are speeded—about 200 a minute—but the feed is regulated by turning the hand-screws I I, which push in or draw out the front plate of the hopper, provided, if necessary, with an indented steel plate for facilitating the crushing of the coal. Sight-holes are made in the

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fan-cases for affording means to ascertain that the fans are properly working; and part of the bottom plate of the fan-case is constructed so as to be easily removable for taking out a fan in case of need. Sliding ventilators, for regulating the admission of air, are also provided in the furnace doors, as shown in the front elevation. The two outside fire-bars remain stationary, but the others have a motion imparted to them by the crank of the short horizontal shaft K, links M, and projecting or connecting bar N. Every other fire-bar, O O, slides on the roller Q, and cross bearer S, while the rest, P P, carried on the rocker R, and cross bearer U, are, owing to the cranked shape of the rocker, made to rise and fall. The ashes and clinker are thus carried in one direction, according to the setting of the cranks. In the arrangement shown in Figs. 4 and 5 they are carried to the back end of the flue, on to a kind of dead plate formed by the ends of the lifting bars, which are continued beyond the sliding bars; they gradually fall into the ashpit at the back, whence they are removed periodically, by means of the hanging door T, worked by the chain V, from the front of the boiler. In this way, as the supply of fuel is self-acting and continuous, so is there also an automatic stirring of the fire and cleansing of the fire-bars continually going on. The amount of rise and travel of the bars is regulated by turning the hand-screw W, according to the nature of the fuel and the demand on the boiler. At the same time this double action of each alternate bar lifting and sliding keeps the interstices between them clear for the free admission of the air necessary for combustion.

All the foregoing mechanical arrangements for supplying fuel to furnaces appear to have been designed in imitation of the supposed perfection of hand stoking—that is, the even distribution of a thin layer of coal over the whole surface of the fire, and as lightly as possible, so as to admit plenty of air for effecting the combustion. In the Frisbie feeder, however, a different principle has been adopted—that advocated by Dr. Arnott for domestic fireplaces. This consists in a supply of fresh fuel being given from below, which, on being subjected to the heat of the incandescent mass above, evolves its gas to be consumed on rising through the fire. The other arrangements are for quick combustion; this one is for slow combustion. In those the feed is continuous, while in this it is intermittent; but the evil in admitting a volume of cold air on the top of the fire is avoided in this case as in the others. In 1868 Mr. Myron Frisbie, of New York, without claiming to originate the idea of feeding fuel from below, patented an arrangement whereby

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coal was thrust up underneath, and in the middle of the fire, and several of his machines are still at work, doing very good service. In 1875 Mr. James Millward Holmes and Mr. Walker, of Birmingham, introduced into this feeder some improvements, which chiefly consist in substituting gear for the direct action of a lever, while at the same time the whole machine is simplified.

Fig. 6 is an elevation of the improved Frisbie feeder as applied to a Cornish boiler; Fig. 7 is a plan of the fire-grate, and Fig. 8 a vertical section, showing the fuel-box in the position for receiving a supply of coal. In place of the usual straight fire-bars is a central circular aperture surrounded by segmental gratings (shown best in the plan, Fig. 7), which are easily removable, while the whole annular arrangement of grate runs on friction rollers, like a turntable, and may be moved round by means of a crowbar inserted in the holes shown at Fig. 6. Underneath the central aperture is the cylindrical fuel-box A, mounted on forked side-frames B B, which swing on pivots F F, attached to the base-plate along the centre line of the fuel-box. Cast in one with this fuel-box is the apron C for retaining the coal when the box is in its inclined position ready for being filled; and jointed to it is the lever D, by the intervention of which the rod E, attached to the movable bottom of the fuel-box, is raised by the crank of the shaft to be afterwards described. A, B, C, D, and E swing together on the pivots F F; but the movable bottom of A is at the same time capable of rising and falling, being retained in its highest position by the catch G, engaging with the nose of the lever D. The crank of the shaft H, mounted on bearings, also arranged along the central line of the fuel-box, carries a friction roller I, which acts in its rotation upon the lever D, and consequently raises the movable bottom of the box. This shaft has also another pair of arms J J, provided with pins which take into notches in the links K K, jointed to the forked plates B B, and thus alter their position from inclined to vertical, and *vice versâ*. The shaft is moved by the bevel gear and winch, either direct in a small machine, or with spur-wheel and pinion in a larger one, as shown in the vertical sections. Assuming that the fuel-box is filled with coal in its inclined position, the winch is turned so as to move the crank-shaft in the direction of the arrows in Fig. 8. The arms J J, by means of the links K K, draw the forked plates and fuel-box underneath the central aperture, when the links rest upon the shaft, locking the box in its vertical position. As the crank continues to revolve in the same direction, the pins leave the notches in the links; and the

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friction roller I comes into contact with the lever D, and raises the movable bottom of the fuel-box, thus forcing the coal upwards into the fire. The bottom is held in this position by the nose of the lever D engaging with the catch G. The winch is now turned the reverse way, which causes the shaft to revolve in the opposite direction. The pins again engage in the links K K, thus pulling over into an inclined position the forked plates and fuel-box, which latter is followed up by the apron C, for the purpose of retaining the coal in the fire-grate. As soon as the catch G strikes the bar L it releases the lever D, and thus allows the movable bottom to fall to its first position, ready for another charge of fuel. Each fresh charge displaces that previously inserted, and so has the effect of moving the whole fire. This action breaks up the cinder, and gradually carries any hard clinker that may have formed to the circumference of the grate, where it is removed at intervals by bringing in succession each part of the segmental gratings before the furnace door by means of a crowbar.

It is evident that this arrangement is not applicable to the flues of Cornish or Lancashire boilers, as they are usually fired; but the Frisbie feeder has been applied with success to these boilers, either in the middle of their length, as shown in Fig. 6, or at one end, in a kind of combustion chamber made of fire-brick, communicating direct with the internal flue. There also seems now to be a reaction in some quarters in favour of externally fired boilers, especially that class in which two or more large horizontal water tubes are connected by smaller vertical tubes.

The "Helix" fire-feeder, devised by Mr. Holroyd Smith, appears to combine, in a modified form, the two principles before mentioned—that is to say, the fuel is fed from below, while at the same time the feed is continuous. Its application differs from that of the Frisbie feeder in its being more suitable for an internally fired boiler, for which, in fact, it was specially designed. In this appliance two or more of the ordinary straight fire-bars are replaced by a trough, in communication, at the bottom, with a tapering case of cylindrical section, in which works an Archimedean screw of modified form. The fuel contained in a hopper, placed in front of the boiler, is thus absolutely screwed into the fire underneath the incandescent coal, so that the gas is extracted by the heat and burnt as evolved. The air necessary for combustion makes its way between the interstices of the bars, which are serrated on their upper edges for facilitating its distribution through the fire.

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Fig. 9 shows a front view of a Cornish boiler fitted with this arrangement, part of which is in section; and Fig. 10 shows a longitudinal section of the boiler, with the "Helix" partly in section and partly in elevation. The hopper H is in communication with the feed-trough F, which is placed across the front of the flue, and communicates in turn with two or more screw cases, according to the size of the boiler. In the drawings, three of these cases are shown, containing the screws S S S. As the screw is of uniform pitch but of gradually decreasing diameter, suitably calculated, it delivers the fuel evenly throughout the whole length of fire-bars B B; and the coal must be forced upwards through the longitudinal aperture, as that is the only outlet. Any large lumps of coal are crushed by the screw before being passed on. The cinders fall over the fire-brick bridge, and are removed once a day by withdrawing the damper D. A is an ordinary fire-door for the inspection of the fire, for banking it up, or for use in hand firing, in case of a break down to the engine driving the feed-gear, or from any other cause. The screws were originally made to revolve by means of ratchet wheels and pawls, attached to a bar caused to oscillate by means of a crank and lever. Subsequently, however, the arrangement shown in the diagrams has been adopted as being more compact—that is to say, worm-wheels on the axis of the screws are turned by worms on a horizontal shaft, running in front of them, and driven by a belt. In the apparatus the author saw working at Halifax, a small engine, of a single man-power, is found sufficient to work two machines fitted to Cornish boilers driving 100 horse-power. Any obstruction to the feed, through any extraneous substance becoming mixed with the fuel, instead of causing any breakage, merely pulls up the engine. By disconnecting the lever the feed can even be worked by hand.

In the foregoing remarks, examples have been given of appliances for automatically supplying fuel to both internally and externally fired boilers, with both quick and slow combustion. In all those of late date, which have been more particularly described, a great saving in coal has been effected. The author has purposely avoided any bare statements as to an economy of so much per cent., or an evaporation of so many pounds of water per pound of coal; for all such statements must be taken in connection with the nature of the fuel and the various attendant circumstances. It may be remarked, however, that the saving is twofold—first, in quality, as a cheaper or smaller coal, when properly burnt, will do the same work as larger coal subjected to imperfect combustion; and secondly,

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in quantity, as for a given power, the whole, or nearly so, of the useful effect of the fuel is turned to account, instead of a large proportion going up to the stack worse than waste. Again, in addition to this saving in current expenditure, there is also that in first cost of plant, owing to smaller boilers and fire-grates serving for a given power. In the event of greater power being required than was originally provided for, the more perfect utilization of fuel by an automatic stoker has been known to save the laying down of an additional boiler—no slight consideration where space is an object.

It is not probably contended, even by the inventors and improvers of the appliances noticed, that they have as yet attained perfection; but, on the other hand, it will readily be conceded that they have made great progress, and have taken a distinct step towards extracting the whole work capable of being yielded by our "black diamonds."

DISCUSSION.

Mr. CARL PIEPER said he had been interested for about five years in the use of the Dillwyn Smith stoker, particularly in Saxony. He had asked one of the professors of the Polytechnic Academy at Dresden to make experiments in order to ascertain the saving of coal by the use of the Dillwyn Smith stoker. A series of experiments, occupying seventeen days, showed that the main saving occurred through the use of an inferior coal. As nearly as he could recollect, the saving in the weight of fuel was not more than between ten and twelve per cent.; but the mechanical stoker enabled them to use a larger proportion of small coal of a much inferior quality than could be used with hand firing. The saving effected in that way was above sixty per cent. The fuel known in England as lignite, which in Dresden was obtained from Bohemia, was compared with black stone coal. It was found difficult to obtain small coal dry enough to be used in mechanical stoking, for in Germany it was usual to wash the residue in the coal mines for the purpose of getting out the slate, and the coal thus treated would not dry sufficiently for convenient use as a fuel, and therefore the experiments with small coal in the Dillwyn Smith stoker were not fully trustworthy.

Mr. PERRY F. NURSEY observed that a very good practical test of the working value of one mechanical firing apparatus, that of Dillwyn Smith, had recently come under his notice. At the works of Messrs. Barnard, Bishop, and Barnard, at

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Norwich, there were four Cornish boilers. Two of them were each 20 feet long by 5 feet 6 inches diameter, with 3-feet flues. The other two were each 22 feet long by 5 feet 6 inches diameter, with 3-feet flues for 14 feet, and terminating in a 3-inch multitubular arrangement. The first two boilers were hand stoked, and the last two were fitted each with a Dillwyn Smith apparatus, which had been at work for two years and a quarter, during which time careful note had been taken of the fuel account. The average consumption of coal during that period with the hand-fired boilers was 18 tons per week. The average consumption with mechanical firing was 14½ tons per week, both pairs of boilers being at work the same number of hours per day, and in other respects under similar conditions. In the case of the mechanically fired boilers, there was a further saving in the coal bill, inasmuch as coal of an inferior quality, as regarded size, was used, the price being 3*s.* 6*d.* per ton less than that used for the hand-fired boilers. During the two years and a quarter the machines had been in operation, the only repairs necessary had been the renewal of the footsteps for the spindles. The men were well satisfied with the machines, and so were the masters, seeing the saving they effected in the fuel bills.

Mr. W. SCHÖNHEYDER said there was great difficulty in getting hand stoking properly done, and the fuel evenly distributed. He wished to know whether the coal in the Henderson stoker was always evenly distributed, or whether there was not a tendency for it to get too far on one side, or to accumulate in heaps, either at the side of the furnace or at one corner. As to the arrangement for clinking the bars, he could well understand that lifting two bars up and down and moving them backwards and forwards would keep them beautifully clean; but he did not see why the clinkers should be delivered beyond the bridge and not the coal, or why the clinker which was below should go to the far end, while the fuel up above should remain where it ought to remain. Was it ever found that the fuel went away beyond the bridge as well as the clinkers? He had not heard anything said in the paper about the saving in labour. It would be interesting to know how many stokers were saved where a number of these appliances were used. The saving of labour was a matter of great importance as well as the saving of coal. He supposed that one man could attend to many mechanical stokers. As to the rollers, he could not see more than one. He supposed there were two, and that they worked one against the other so as to crush the coal.

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Mr. PEARSE said there was only one roller in each flue, and it worked against an indented plate.

Mr. SCHÖNHEYDER said, that being so, in case larger coal was being used it would be necessary to crush it down before throwing it into the hoppers. The Frisbie feeder, in his opinion, was not so good as the Henderson. The arrangement below was very complicated, and he should think there would be a difficulty in getting the grate cleaned. They would need to rake it, and poke it, and, of course, it would be difficult to get rid of the clinkers. He should say also that there would be something wanting in Fig. 7, as it would be almost impossible for any stoker to throw the hopper full of coal without spilling a great portion of it among the gearing and on the floor. The arrangement seemed to be imperfect in that respect.

Mr. THOMAS HENDERSON said, in reference to his stoking machine, that it would appear that the coal would be thrown in upon both of the furnace sides more or less, but the fact was that the right-hand fan threw the coal to the left side of the furnace, and opposite to the other fan, so that the coal crossed and went to the centre. It was found in practice that the coal was evenly thrown over the whole surface of the furnace. The fuel was only thrown for a certain distance on to the bars, very near the back end of the short bars, and it was gradually taken over by the moving bars; but the motion of the bars was so very small that nothing went over but the clinker. The bars moved only about once a minute, and the travel was only about three-quarters of an inch, and therefore it would take an hour for the whole of the coal to go over the bars. In practice two-thirds of the coal was burnt at the back end of the furnace, so that very little coal ever went over the back end of the bars. The crusher was a small roller with different numbers of teeth, the number depending entirely upon the quantity of fuel required. He found in using the mechanical stoker that there was a considerable saving in fuel. He had fitted one steamer—the 'Lisbonense'—which had been running for more than two years and a half, and in which they had got about the same result from slack as they before obtained from Welsh coal, which was considered about one-third better than north-country coal. The tear and wear of the machines was found to be very little, and that on the bars was also very small. In the case of ships, the bars were moved by hand. The consumption of coal on board the 'Lisbonense' in the two years and a half was over 7000 tons, and only two new bars had been required during that time. He had fitted altogether about

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ten steamers, and it was found at sea that the saving averaged about 40 per cent. The saving in coal at sea was not limited to the coal actually saved in burning, but included the saving of coal from being thrown overboard. In cleaning a very thick fire at sea, a great deal of coal was pulled out with the clinker. The mechanical stoker also reduced the temperature of the stoke-hole in the 'Lisbonense' from 140 to 106 degrees. With careful hand firing 7 lbs. of water could be evaporated with 1 lb. of good slack; with the mechanical stoker carefully worked as much as 10 lbs. had been evaporated with 1 lb. of good slack under the same boiler.

Mr. J. H. ADAMS asked the cost of fitting a boiler with the mechanical stoker.

Mr. HENDERSON said the cost of fitting the apparatus on board a steamship was greater than that of a land boiler. For a boiler similar to that shown in the diagram, the cost would be about 180*l.* for the apparatus fitted complete. It was necessary to drive with a separate engine on board ship, because in heavy weather, when the engines were running slowly, it was necessary to run the machine a little faster. The cost of fitting a land boiler complete would be about 90*l.* The registered tonnage of the S.S. 'Lisbonense' was about 1000 tons, and she was burning about 2 lbs. of slack per indicated horse-power.

Mr. BARNARD P. WALKER, referring to the Frisbie furnace, said that the coal being filled into the hoppers when they had been moved forward into a convenient position, there was practically no waste in filling the charge of coal by hand. The machinery seemed complicated, but it was really much more simple than it appeared. One of the feeders had been in operation in his own factory for eighteen or twenty months, and it continued to work with the same accuracy as at starting. With regard to the formation of clinkers, he would observe that the charge of fuel was pushed into the centre of the grate, so that the clinkers were forced to the outside of the circumference, and were removed with great facility. In his own case the apparatus had been applied in a way which was, perhaps, exceptional. It was under a "Root" multitubular boiler, fired externally. The consumption of coal with hand firing was 24 cwt. in nine hours. That was, of course, most wasteful, for the draught was insufficient to burn such a quantity thoroughly. The Frisbie feeder had reduced the consumption from 24 cwt. to 8 cwt. in the nine hours. That feeder was not so applicable, in his opinion, to boilers as it was to furnaces, such as glass furnaces and muffles, where a very thick fire was required in

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order to obtain a very high temperature in a vessel of large capacity. The saving effected in such a case arose from the fact that the whole fuel was burnt.

Mr. VAUGHAN PENDRED said that the three great considerations with any new mechanical contrivance were what it would cost to apply, what would be gained in return for that cost, and how far the invention would interfere with existing arrangements. He was very much in favour of mechanical stokers, and therefore disposed to lean towards some system which would supersede ordinary hand firing. Neither the author of the paper nor any of the speakers had approached what was really the gist of the matter, which was, What would the various systems cost to fit? How long would they last? What was the saving to be effected? And what was the gain to be derived from their employment? He understood from Mr. Henderson that it would cost from 85*l.* to 90*l.* to fit the two furnaces of a Lancashire boiler with his mechanical stoker. At that price he (Mr. Pendred) would be within the mark if he said that it was one-third of the whole cost of the boiler, without counting the setting. Supposing that he fitted the apparatus to a bank of boilers, the first question would be, What was the direct pecuniary result? If he turned to Frisbie's arrangement, he was met with Mr. Walker's statement that the feeder was not applicable to internally fired boilers. Then, looking as a manufacturer at Frisbie's feeder, and Holroyd Smith's helix stoker, the same questions arose as to results. He should like to have some definite information as to the pecuniary merits of the different systems, for such facts would be interesting to engineers. There was nothing easier than to get an incompetent person for a stoker. The lowest price he had known paid to a stoke, was 3*s.* 6*d.* a week, and the boy who acted in that capacity had various other duties to perform as well. Then stokers could be had up to 30*s.* or 2*l.* a week. Were the mechanical stokers to be pitted against a boy at 3*s.* 6*d.* a week, or against a trained stoker at 2*l.* a week? That point must be settled before they could draw any comparison as to the pecuniary saving. One gentleman had spoken of 60 per cent. saving on one ground, and 9 or 10 per cent. on another, through the use of the mechanical stoker. That gave a total saving of 70 per cent. If that saving could be realized, it showed that the mechanical stokers would enable 30 lbs. of fuel to suffice where before 100 lbs., or the pecuniary equivalent, was needed. Many of those present knew to what perfection hand firing could be brought. He had himself seen a portable engine run

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for five hours, working with 14 lbs. of coal per horse-power for that time. The result as it worked out was that the consumption of fuel on a high-pressure engine worked down to about 2·8 lbs. per horse-power per hour. During the five hours that the run lasted the pressure of steam never varied one pound up or down from 60 lbs. The feed-water was put in at 300 degrees. If the mechanical stoker was pitted against a trained stoker who could produce such a result, the comparison would be rather bad for the machine. There were some circumstances under which a machine-firing system was obviously inapplicable. For instance, no system would ever answer for locomotive work, for a machine could not be varied to meet all the requirements of the road and the trains and so on. He had heard with surprise, and with pleasure, that Mr. Henderson had been successful in introducing a good system of mechanical firing at sea; but he wished to know whether the boilers which Mr. Henderson had been working with at sea were high or low pressure; and he also wished to know what Mr. Henderson would do if he had an accident with any of his flues.

Mr. NURSEY said that one of the questions proposed by Mr. Pendred was answered in the case of the use of mechanical stokers at Mr. Barnard's works, to which he (Mr. Nursey) had already referred. Those machines had been in the charge of the same men that did the hand stoking. When Mr. Pendred mentioned the example of hand stoking and the remarkably low comsumption of fuel in connection with the portable engine, he omitted to state that the experiments were competitive, and so careful was the stoking, that the last few grains of coal were scraped together and sprinkled on with the fingers. That was at the competitive portable engine trials at Cardiff.

Mr. HENDERSON, referring to Mr. Pendred's remarks, stated that the mechanical stoker did not at all interfere with hand firing if anything went wrong with the machine, for all the bars were provided just as in hand-fired boilers, and if the mechanical stoker got out of order they could fire the boiler just as before the machine was fitted. If new rivets had to be put in the flues, the bars of the machine could be lifted out in the same way as ordinary bars. If the machine should get out of order, it could be thrown out of gear, and the bars could be rocked by hand by means of a lever. With regard to the pecuniary result, in one vessel which had eight furnaces fitted with the machine at the cost of 720*l.*, the owners acknowledged a saving of 1300*l.* a year. He believed the pressure of steam carried in that vessel was 70 lbs. per square inch. In order to

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drive the machine for eight furnaces, a small engine of about 4½-inch cylinder, running at about 120 strokes, was required. There was very little waste of power, because the small engine exhausted into the condenser of the large engine.

Mr. HOLROYD SMITH said that, in considering the merits of the various mechanical stokers, it was necessary to go back to first principles to some extent. It was well known that only a given quantity of air was necessary for the complete combustion of coal, and modern experiments had fixed the quantity for economical generation of heat very much lower than it was fixed at thirty or forty years ago. It was argued in times past that it was necessary to admit air through the fire-door, because a sufficient quantity could not be admitted through the grate. In practice, however, all good hand stokers kept their doors closed as much as they could, and, as far as possible, made all the air go through the grate; and although a reduction of smoke was effected when air was properly admitted through the door, it was attained at a sacrifice of heat. Mr. Dillwyn Smith was not the father of the principle involved in his machine, that principle having been first introduced in 1813; but subsequent inventors had built upon the original idea, until at last the machine had resulted in the Henderson stoker. The arrangement for moving the bars was, perhaps, the most valuable addition to the machine which had ever been made. The revolving fan not only threw the coal on to the fire, but it also introduced a current of air. The aperture through which the coal fell, and through which the bearings of the fans and the other arrangements about that part passed, allowed the air to enter the furnace just where it was not wanted, viz. at the top part of the boiler plate. The air thus admitted cooled the gases which rose from the coal, and the result was that, in the Henderson stoker, instead of there being a clear bright fire, there was a cloudy mass travelling forwards up the flue. If the admission of air could be stopped at the front, there would be a still greater economy with the Henderson machine. The practice of mechanical firing was often adopted for the sake of getting rid of the smoke and smoke prosecutions. The Henderson stoker got manufacturers out of that difficulty, for when it was used, there was no dense smoke ever emitted from the chimney, but instead of that, the smoke was "rolled thin" during the whole of the day, and thus there was a constant slight emission. He suspected that as large, or even a larger, total quantity was emitted from the chimney during the day; but inasmuch as the smoke did not come out in a dense volume

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for ten minutes, the lucky manufacturer escaped prosecution. The Vicars stoker was a very valuable one, and was coming extensively into use. The economy of coal resulting from that stoker and the perfectly clear chimney top which it secured were most satisfactory. Having found, when turning his attention to mechanical stokers, that the smoke rolled continuously when Henderson's class of stoker was used, he came to the conclusion that, theoretically, the only correct method of supplying fuel to the fire was from below. But the difficulty was how to apply that method to internally fired boilers; that engrossed his attention for some time, and at last he hit upon the helix furnace feeder. With that apparatus he attained all the results in economy and smokelessness which were derived from the Frisbie and from the Vicars feeders with greater simplicity of parts and a cheaper machine. It had been stated that the Henderson cost about 90*l.*, but it had been found that, including fittings, it cost 120*l.* before it worked. The helix furnace feeder cost between 50*l.* and 60*l.* per double-flued boiler, according to the size of the flues. That, of course, was exclusive of the driving shaft.

Mr. ALFRED MARSHALL said he doubted the efficiency of such machines to thoroughly consume smoke. It seemed to him (as a boiler manufacturer) that Mr. Pendred had really hit on the practical part of the question, viz. what was the cost of such apparatus. It was not supposed by the inventors of those stoking machines that they could be applied to locomotive or vertical boilers, but still it did not at all follow that machines which would not be applicable to such boilers might not be not only applicable, but valuable, for other boilers. He could understand that in a row of Cornish boilers, one stoker might work three or four machines, whereas three or four men would be required for as many boilers, and hence there would be a great saving in that respect. He was sure, however, that manufacturers who paid 200*l.* or 300*l.* for a boiler, would not go to the expense of the Henderson machine. If the expense of such machines could be brought down to 20*l.* or 25*l.*, they would perhaps meet with general adoption, but the present prices were prohibitory.

Mr. HOLROYD SMITH stated that the helix feeder had been applied to a locomotive boiler.

Mr. JAMES SMITH said there was no doubt that the elementary part of the question was well understood and was correctly described by Mr. Holroyd Smith when he referred to smoke in connection with the Henderson stoker. Those who were

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engaged in experiments knew that the system of firing at the front was the one most favourable to the efficient and economical prevention of smoke, the object being to obtain perfect combustion with the smallest consumption of atmospheric elements. That was done in hand firing, by feeding or coking at the front of the furnace and pushing the coked fuel backwards each new charge. One of the advantages of stoking machines over hand firing was that the machine did its work with much greater certainty and regularity than was possible by hand firing.

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March 19th, 1877.

THOMAS CARGILL, PRESIDENT, IN THE CHAIR.

THE MECHANICAL FIRING OF STEAM BOILERS.

ADJOURNED DISCUSSION.

Mr. A. RIGG, in opening the discussion, observed that the Henderson stoker appeared to act very well, but the Frisbie system appeared most applicable to vertical boilers, because of its circular form. Mr. Holroyd Smith's was an exceedingly ingenious arrangement, but considering the way in which ordinary furnace bars were burned up and destroyed, it did not seem likely to possess very great durability; the screw was liable to burn out. That, however was a matter of opinion, and experience might show that the invention was more enduring than would appear from a mere theoretical criticism. There was one point that occurred to him in all these various contrivances, namely, the large amount of machinery which was involved in the process of scattering coal over the surface of the bars, or bringing it up from underneath. He had heard it stated that the amount of air required by some processes was nothing at all, whereas in this case there seemed to be a certain amount. That was probably due to the kind of coal used, for it was well known that bituminous coal required air to burn the gases, whereas anthracite and similar sorts of coal did not require any. Some years ago he saw an apparatus for feeding boilers which appeared to do all that those in question did with the utmost simplicity. It consisted mainly of two blocks of cast iron, which were moved backwards and forwards through oblong openings in the furnace front. The coal was heaped above, and at every movement of the blocks a portion was pushed forwards into the furnace. The apparatus was of such an exceedingly simple character, that it appeared to him to be worthy of development in the same way as Henderson's stokers had been improvements on previous inventions.

Mr. VAUGHAN PENDRED said that a stoker of the kind described by Mr. Rigg was at work at the New Post Office in

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St. Martin's-le-Grand. It was fitted, he believed, to eight Lancashire boilers, and had given great satisfaction, at the time he saw it, which was two or three years ago. Messrs. Eastons and Anderson had adopted it without hesitation. The stoker was not quite so simple as it appeared to be from Mr. Rigg's description. The arrangements at the Post Office were very elaborate, and included the use of an endless chain of buckets for carrying the coal along the top of the boilers, from the coal store, and tipping it into the hoppers; and instead of there being only one feeder, there were two to each grate. There were two sliding blocks worked one at each side of the door. The door was very small, and was fitted with air apertures. The sliding blocks caught the fuel as it fell from the bottom and pushed it into the furnace. The apparatus was probably very nearly as complex as the Henderson stoker, as far as cog-wheels, straps, and belts were concerned.

In the course of the last discussion, Mr. Holroyd Smith referred to the fact that the Henderson stoker admitted a large quantity of air above the fire-bars, and he pointed out that such an admission of air was unnecessary. He (Mr. Pendred) thought that a great deal of nonsense had been advanced about the admission of air above fire-bars, and that very contradictory reports had been issued on the subject. About eight or ten years ago considerable pressure was put by an Act of Parliament upon the owners of the tug boats in the Thames to compel them to adopt some system of preventing smoke, but the result was a failure to keep the steam up to the proper pressure so long as the different systems of admtiting air above the fire-bars were being tried, and the conclusion was arrived at that the only system of getting rid of smoke consisted in using a coal which did not produce it. Still it could not be denied that, as a rule, with most coals and stokers and boilers, unless air was admitted above the fire there would be smoke. The system as carried out by Mr. Holroyd Smith appeared to be successful for the reason that he kept an exceedingly thin fire, and by doing so he admitted as much air as might be required for the total combustion of the coal and of the products of combustion through the bars. So long as a thin fire was carried there was practically very little smoke; but the great difficulty that followed was that the fire was liable to burn into holes, and then too large a quantity of air was admitted through the grate. Some time ago he witnessed an experiment illustrating the difference between admitting air above the furnace and below it. A Lancashire boiler was fired with a very heavy fire and the admission of air was brought down to something like 13 lbs. of air per lb. of coal. There was a great

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deal of smoke, but that boiler was really more economical and evaporated more water than another boiler beside it, which had an almost unlimited supply of air above the bars, and produced no smoke whatever. The reason why a boiler working with a forced draught would do with less air above the furnace than a boiler working with an ordinary draught, appeared to him to be simply that the air was brought into more intimate contact with the gases under the influence of a forced draught. The introduction of a simple brick arch across the fire-box had effected what very elaborate systems of admitting air as originally tried had hardly done, the air being thoroughly well mixed with the products of combustion. As bearing upon what Mr. Smith had said about the admission of air above the grate bars being wrong, he (Mr. Pendred) might mention that on the Brighton Railway he had run for many miles on engines in which practically little or no air was admitted through the fire-bars. Both the dampers were kept close, and almost the whole of the air was admitted through the fire-door turned down under a scooped deflector on the fuel and thrown back again by the brick arch. That was an instance of forced draught, where nearly all the air was admitted above, and the process that was carried on there was no doubt the gradual evolution of the products of combustion from the fuel on the grate and a subsequent combustion at a high temperature when it encountered the air coming in through the fire-bars. To ensure success in such a case as that, it was obviously necessary that the brick arch should be intensley heated, because if the engine went out with a comparatively cold brick arch there would certainly be smoke in the first instance, and probably want of steam before long. He thought that no rule could be laid down as to whether air was to be admitted or not above the fire-bar until it was known precisely what coals were to be used and what the conditions of running were to be. On the Brighton line—which he took as a typical example, where fuel was used to the best advantage—the consumption of fuel had gradually been worked down from 30 lbs. to 27 lbs. per train mile, simply by care in firing. On that line the practice was to carry a very heavy fire, the express trains running from London to Brighton with one fire, and the admission of air being almost wholly over the fuel. Mr. Holroyd Smith had a totally different set of conditions to deal with. He had a Lancashire boiler with a very cool place close over the fire, and he had no practical opportunities of burning the gases after they had once left the fuel. He was not at all certain that Mr. Holroyd Smith's system as applied to Lancashire boilers was not the best. If applied to an externally

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fired boiler with large grates it was quite possible that a better result would be obtained from carrying much heavier fires than it appeared possible for Mr. Smith to carry. There could be no question that every pound of air that was admitted into a fire-box more than was actually required was a loss. He should like to know what kind of coal Mr. Holroyd Smith had been using, and what had been the evaporation per pound of coal with the Helix feeder, the Frisbie, and the Henderson stokers as compared with the ordinary hand-fired boiler. He could not believe that any such saving as 60 per cent. had been effected by any stoker. It was desirable, however, that some definite information on that point should be afforded.

Mr. T. SMITH said that of all the mechanical furnaces that had been used (excepting the Vicars), the Juckes furnace had been the most successful; one defect in the original Vicars, as in the Juckes, was that ignition commenced at the top, and until the fire had penetrated the mass, there was a considerable amount of riddling of unburnt fuel through the bars. In the Vicars stoker that defect had been corrected by introducing the fuel some distance above the bars, and forcing it direct on to the fire. The fuel was spread, and had a progressive motion given to it by simply moving the bars forward, *en masse*, and bringing them back in detail.

Mr. T. HENDERSON, referring to the large amount of air said to be admitted into the fire-box, said there was a very small quantity admitted, just sufficient to keep the bearers cool. Mr. Smith had objected to studs in flues; but he (Mr. Henderson) thought a stud put into the flue properly was not more objectionable than a rivet. The cross bearers and the fire-bar resting on them must sometimes be red-hot, and they must be greatly expanded. In a furnace, say 2 feet 6 inches by 3 feet, the cross bearers would expand not less than a quarter of an inch, and there would be a great strain in the flue of the boiler; but as the furnace was cooled down they would naturally contract again, and a great strain would be thrown on the boiler. In that case the bearers were shorter, to allow of free expansion and contraction. He had made some experiments with the Henderson stoker some five years ago. There were nearly 9 lbs. of water evaporated per pound of slack, which was not of the best quality. The boiler was previously tested with Welsh coal, and the evaporation of water with a single flue was 1800 gallons in twelve hours by hand. With the mechanical stoker and with slack about two-thirds of the price, the evaporation was something like 2700 gallons, and the saving in cost was about 30 per cent. The fires could not be very much

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forced with Welsh coal, but with mechanical stoking there must be rapid combustion, or there would be a loss. With the Frisbie stoker from 20 to 40 lbs. of slack could be burned per square foot per hour. He knew one case in which the evaporation of a double-flued boiler in ordinary meal hours was 9200 gallons, and the average by hand was 5500. The average with a mechanical stoker in six months was 7500. Frost's mechanical stoker was identical with Henderson's with the exception that it was worked by belts instead of friction, but the means of throwing the coal on was exactly the same. If he remembered rightly, the bars tumbled down on the angle irons. Ordinary bars were generally of two lengths, but with the Holroyd Smith system was a cross bearer in the centre of the bars, the air was baffled to a certain extent, and that part of the fire was left thick or thin, because the combustion was not so rapid above the bearers as it was at the other parts of the bars; so he found it much better to use the bar in one length. He thought the results would be even better in Frost's case with movable bars.

Mr. HOLROYD SMITH said that Mr. Rigg had expressed a fear that the screw of the Helix furnace would burn out by the heat of the fire; but in practice he (Mr. Holroyd Smith) had found that the screw remained only just warm. The screws improved the longer they were used, because they became polished and allowed the coal to slip more freely. The durability of the screw was almost unlimited, and when worn out could very easily be replaced at a cost of about 15s. With regard to the question of economy, in working, knowing what had been used per month before and after the introduction of the machine, he found that the economy averaged from 15 to 25 per cent.; although the machines had been fitted to boilers where they had excellent hand firers at work before. He considered the mechanical stoker of Messrs. Vicars to be one of the most successful he had ever seen at work. Mr. Pendred was wrong in supposing that he (Mr. Smith) employed a thin fire with the Helix furnace feeder; for he had employed a fire from 8 to 10 inches thick. The thickness of the fire was only limited by the diameter of the flue. He allowed it to go within 6 inches of the flue-top, and when the door was opened the air was seen rushing against a mass of incandescent fuel.

With reference to Mr. Pendred's remarks as to admitting air over the door in a locomotive, he thought the success in that was entirely due to the deflector plate and to the fire-brick. The fire-brick played a very important part, because when it became hot it acted almost as a fire above the fuel. The chief danger

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of admitting cold air was that it cooled the gases down below the temperature at which they would ignite; but with the hot fire-brick the air was kept at the proper temperature for mixing with the evolved gases. Before the introduction of his machine, in order to abate the smoke nuisance, he introduced a fire-clay beehive at the back of the bridge, which was raised to a white heat, through which the air was admitted and raised to the same temperature as the gases passing through the furnace, and in that way there was an almost perfect consumption of the smoke. Mr. Henderson was in error in reference to the cross bearer of the Helix furnace feeder becoming red hot. He had never found it become so. Where the back bearer rested upon the boiler-plate it was considerably below the centre of the flue, and even if it were given to expand, the force was upward and not crossward, and no strain could come upon the boiler.

Another important point was what effect would mechanical stokers have upon the boilers. It was a very anxious question with him, and he took very great care that no improper strain would come either upon the flue or the front plate. The main difficulty in mechanical stoking, as evidenced by the repeated patents of the Messrs. Vicars, was in reference to the end of the furnace where the coal fell over into the flue bottom. The difficulty occurred from the end of the bars burning out too rapidly, by reason of the intense fire that was congregated in heaps at the bottom of the furnace. Water tubes of various devices had been introduced to prevent that; but the addition was a very costly one.

Mr. T. SMITH said that the water tube was merely a tube passing from one side of the boiler to the other, and his experience had been that the heat was so great that no wrought-iron tubes would bear it, and no bridge or screw could endure a heat of that character unless it generated steam.

Mr. HOLROYD SMITH said that he experienced the same difficulty in the Helix furnace feeder. He introduced the fire-brick, but it was not altogether satisfactory. The success of the system of letting the cinders fall over the back and raking them out from below was so great that it had led Messrs. Henderson to adopt the same principle in their stoker, and though destructive of the ends of the bars he did not wish to abandon it. Nor did he wish to adopt the risky and expensive expedient of a water tube. Very recently he completed an arrangement which got him out of this difficulty. Instead of allowing the coal to fall immediately into the boiler bottom, he took it on to a subsidiary grate consisting of a set of bars, placed crossways in the flue, connected with a link at the front of the

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furnace, and when the fireman wanted to clean out at the back he pulled a handle, and the bars immediately assumed an upright position, and allowed all the cinders that were on them to fall into the boiler bottom. They were then pushed back again and the clinkers raked out, and more coal was pushed over on to the bars. That fully guarded against the end of the furnace bars burning out, and obviated the necessity of water tubes.

Mr. HENDERSON asked what the consumption was per day.

Mr. H. SMITH said that in the furnace attached to their Cornish boilers the flues were only 2 feet 6 inches long. When fired by hand the fire-bars were 6 feet long. He had reduced them to 2 feet 10 inches, giving for the two boilers rather more than 10 square feet of fire surface, upon which 35 cwt. of coal was burnt per day, a result which he thought very good indeed; but there was an exceptionally good draught in those boilers. He had, however, abandoned the idea of successive combustion upon a small area, and was as far as possible increasing the area of the fire-bars. He had also machines working where the draught was very poor; there were three large boilers 30 feet long and 9 feet in diameter, with two flues 3 feet 2 inches in diameter, all going into one chimney, 4 feet square and 20 yards high. There was a great risk in employing a stoker in a situation of that kind, but he was happy to say his boldness had met with reward. The machines were doing good service, and promised to be very durable: they were burning about 90 tons of coal per week. One recommendation of the Henderson stoker was that, with exception of the numerous holes bored in the boiler for set screws, no damage was likely to result to boilers from its working; but in the class of stoker of which the Vicars might be taken as a type, the coal fell from the hopper on either side of the fire and was pushed by the plunger on to the fire-bars. As the combustion was most fierce at the point of impact of green coal with the burning mass, owing to the evolution of gases, there was a risk of the fire burning too far back into the bottom of the hopper; then the most intense flame would impinge upon the angle iron that connected the flue with the front plate, and there would be great danger of burning it through: he knew that as far as possible this was guarded against, but the danger still existed.

Mr. HENDERSON said it was evident that Mr. Smith went in for slow combustion, because with two boilers similar to those shown it might fairly be expected that he would get through at least from 3½ to 4 tons a day with Henderson's stoker; so that instead of diminishing the number of boilers, he

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thought Mr. Smith had increased it to 30 per cent. Two tons a day for a single flue boiler was considered pretty good work. He had a series of stokers burning at the rate of 11 tons each in twenty-four hours. It did not follow that because the combustion was rapid there was a loss. He had seen one of Vicars' furnaces, he believed the only one he ever saw on a double-flued boiler, and he thought the consumption was close upon 4 tons per day, showing that the combustion was not slow in that case. He did not think Mr. Smith could get through very much coal with ten engine fires, but of course a good deal would depend upon the draught.

Mr. HOLROYD SMITH said that he burnt under his boilers only such coal as was necessary to drive the works, and not for the sake of showing how much he could make the stoker do. He might get 5 cwt. if he desired.

Mr. HENDERSON said that the question asked was the amount of fuel burnt per square foot.

Mr. PENDRED said he made the quantity per square foot to be 36 lbs. per hour.

Mr. T. SMITH said he had recently witnessed at Saltaire a test of eight hours' duration with a Lancashire boiler, with a consumption of 9 cwt. per hour, the flues were 3 feet 6 inches in diameter, the draught was feeble, showing on a draught gauge less than three-eighths of an inch. He observed that in all tests the character of the fuel burnt, the amount of draught acting on it, and the size of the furnace must be considered.

Mr. P. JENSEN thought the size of the pieces of fuel must have something to do with the success of mechanical stoking.

Mr. H. W. CHUBB said that at present at his works there was a double Henderson stoker, fitted to a Cornish boiler, 6 feet 6 inches in diameter, with a double flue. A few months ago, when they commenced using the stoker, a saving was effected of 2*l.* 16*s.* 6*d.* per week of sixty hours, the pressure maintained being from 45 to 50 lbs. The size of the coal had been rather a difficult matter with them, and they had scarcely been able to get it small enough, but he had supposed the pieces were about the size of broken walnut-shells. Perhaps the only difficulty to be contended with in all stokers was that of deleterious matter getting into the hopper.

Mr. HENDERSON thought the size of a bean was a very good size, but if it was first coal it should be about two inches square.

Mr. T. SMITH thought that in most cases it was preferable to introduce the coal in moderate sized pieces. Common fuel or small coal was used because it was cheapest, but for marine

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purposes, and if used in an economical way, larger pieces were preferable.

Mr. S. REGAN said a true mechanical stoker should be able to get rid of refuse. He gave the following particulars of a recent trial of one of his furnaces at Messrs. W. T. Henley and Co.'s Works, North Woolwich:—

DIMENSIONS OF BOILER: 33 FEET LONG 7 FEET DEEP, WITH FLUE TUBE 3 FEET 2 INCHES DIAMETER, HAVING ELEVEN GALLOWAY TUBES.

Fire-grate, 6 feet by 3 feet 2 inches, equal to 19 square feet.
Coals consumed in one hour = 298 lbs.
Water evaporated in one hour = 52·1 cubic feet.
" " per 100 lbs. of coals = 17·5 cubic feet.
" " per lb. of coal = 10·5 lbs. of water.
Coals consumed per foot of grate = 15·8 lbs.

The above is an average of a three hours' trial. Temperature of feed water about 110 degrees, not tried at time of trial.

Mr. J. W. PEARSE, in reply, said that he believed the three inventions brought prominently forward in the paper had effected very great saving. As Mr. Holmes, the improver of the Frisbie feeder, was not present to give actual facts, he must quote some independent testimony; but first he would observe that the Frisbie feeder made so hot a fire that it was used successfully in the reduction of cobalt and nickel ores. The Patent Steam Boiler Co. of Birmingham, who has three feeders in use, stated that formerly 1 lb. of common fine slack evaporated 5½ lbs. of cold water; but the same quantity when used on the Frisbie grate evaporated at least 7 lbs., thus showing a saving of over 25 per cent. in fuel. Messrs. John Barnsley and Sons, who had applied the feeder to a cylindrical boiler, stated that they effected a saving of 35 per cent.; and Mr. Walker found that at the Eagle Foundry, Birmingham, under a Root's tubular boiler, the consumption of fuel was reduced below one half.

Mr. SCHÖNHEYDER asked how it was that, in the new Henderson stoker, the clinkers became separated from the coal when they travelled the same journey. The fact was that they both started together, but during transit a great change took place. The oxygen of the air, united with the carbon of the coal, went off in gas, and left the incombustible matter to continue the journey, and be deposited at whichever end was arranged. Independently of the economical aspect of the question of mechanical stoking, there was the humanitarian point of view, for stoking was a degrading kind of labour.

The PRESIDENT said he believed that the ultimate introduction of mechanical stokers would not depend upon any

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humanitarian view, but simply upon the question of their economy. There was one point that struck him as worthy of notice. It was that mechanical stokers had not yet found their way generally into the ships of Her Majesty's navy. Mechanical stokers were, however, upon their trial, and their future success would depend upon their merits. The question of establishing mechanical stokers had been first started nearly fifty years ago, but there was still room for some improvement in their details.

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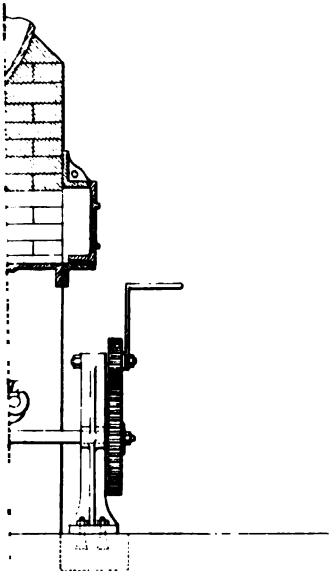
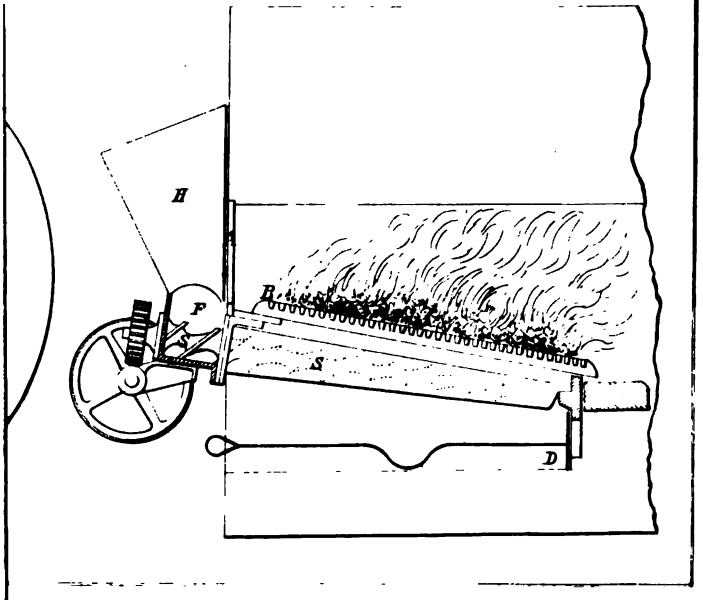


Fig. 10.



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April 9th, 1877.

THOMAS CARGILL, PRESIDENT, IN THE CHAIR.

THE PRIMING OF STEAM BOILERS.

By WILLIAM MAJOR.

Some time since the author read a long article in an engineering publication on the boiler fatalities on board Her Majesty's transport ship 'Serapis,' on her voyage out to India with the Prince of Wales. The substance of that article was that the engineering profession was still ignorant of the real cause of what is technically called "priming." It is certainly humiliating for the profession to be obliged to admit that one hundred years after the introduction of the steam engine they are still unable to subdue an evil so generally experienced as the priming of steam boilers; yet such is the case, as proved by the 'Serapis.' The first question to be solved is: What is the cause of priming in a steam boiler? And until this question is satisfactorily answered, engineers will still go on devising mechanical contrivances for obviating it, and their efforts will end in as many signal failures as hitherto. If we ask a practical engineer what the cause of priming is, we generally have dirty water assigned as a reason, and a specific is given for its prevention; or, what is more usual since the more general introduction of high-pressure steam boilers, some remarks not very complimentary to the constructor of the boilers of which he may have charge, and the priming of which he is unable to master. If we ask the same question of a scientific man—a professor of chemistry for example—he will answer that priming is ebullition, caused by the action of heat on the body of water contained in the boiler, but he is not quite certain as to whether this so-called ebullition is a chemical or a mechanical action. With this meagre information the profession has had to content itself, enduring at the same time all the evils attendant thereon.

In the case of the 'Serapis' we have a ship engined with a power sufficient to propel her through the water with a speed of 13 knots an hour, but that engine power was so paralysed

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through the priming of the boilers that her speed was reduced to 9 knots. The case of the 'Serapis' is by no means exceptional, the same evil obtains in a greater or less degree on board every steamship afloat, and the introduction of high-pressure steam together with the surface condenser has very considerably increased the evil. Indeed, break-downs from large bodies of water passing with the steam from the boilers to the cylinders of the engine are daily occurrences, and more valuable steam engines are destroyed from this cause than from all other causes put together. The author need not enlarge further on the subject of priming and its consequences, but will observe that he feels sure of having discovered a better theory for the cause of priming in steam boilers than is yet generally known. He has also found a practical means of preventing the evil, and that too without putting shipowners to any expense, but, on the contrary, since to stop priming is to save fuel. The author does not propose any costly or complicated machinery for the purpose of preventing priming, not even a wooden deck placed in the boiler, as it was stated was adopted in the 'Serapis' boilers. As before stated, the cause of priming is said to be ebullition in the body of water contained in the boiler caused by the heat acting on the water. The author is bold enough to alter the word "ebullition" into the more intelligible word "friction," and he ventures to assert that priming in steam boilers is—as nature's simple law ought long ago to have taught us—caused by friction on the outer surfaces of the steam globules as they pass up through the overlaying body of water in the steam chest, the amount of such friction being always in due ratio to the velocity at which they pass through the body of water, and also depending upon the state of the water as regards its purity. In other words, the friction is least when the water is pure—distilled—while it is the greatest when the water is charged with all the organic and inorganic matter it can hold in solution. The author is only now, after four years' practical experience on a large scale, publicly making the above assertion, and with the full conviction of its correctness.

Having satisfied himself as to the feasibility of the friction theory, it occurred to him that we had mistaken the real effects or action of the old-fashioned system of injecting melted tallow into boilers for stopping their priming. The reason generally given why tallow or other fatty matter stops priming is because it spreads itself over the surface of the water and quiets it. The author, however, does not believe this is the case, since whenever there is a pressure of steam in a boiler, any fatty

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matter injected into it immediately diffuses itself throughout the whole contents of the boiler, both water and steam. That this is the case can be proved by simply drawing a glass of water from any part or height of a boiler charged with tallow, or by condensing a portion of the steam. The taste and smell of tallow will be found in both cases. The author believes that fatty matter stops priming by lubricating the globules of steam as they pass through the overlaying body of water, reducing the friction on their surfaces, and, as a natural consequence, causing them to carry less water with them into the steam chest. So long as we continue to supply a boiler with a sufficient quantity of fatty matter, priming will not take place. But it so happens that we cannot use the quantity of tallow, nor indeed of any other ordinary fatty matter necessary for the purpose, without producing other evils which it is difficult, or even impossible, to contend with; at the same time the expense of their use would be greater than most shipowners would like to bear. Tallow contains so much insoluble matter, that if used in the required quantity it would soon choke the boiler up; while both animal and vegetable oils contain so much gummy or resinous matter, that they would soon cause evil effects on the interior of boilers if large quantities were used. Of all the patent compositions the author has seen or heard of, he has found none that will answer the purpose—at any rate neither for marine nor for locomotive purposes, simply because the chief cause of priming—impurities in the water—is never absent. Therefore what is required is a constant supply of the proper lubricating matter to prevent the baneful action of these impurities on the globules of steam as they are generated. For marine boilers in particular, too great a stress cannot possibly be laid on the simple fact that the cause of priming is never absent so long as the boiler is in use, or supplying the engine with steam, because the water pumped into the boilers always contain either organic or inorganic matter. And this is the case whether the engines are or are not fitted with surface condensers. If the engine is fitted with surface condensers, priming will in most cases be more severe than with the injection condenser, because the action of heat on the metal plates of the boiler is more intense where there is little or no lime on the plates, as with a boiler fed from a surface condenser, than from an injection condenser, where the water is constantly being changed, leaving all its organic and inorganic contents, with the exception of common salt, in the boiler. Consequently a constant supply of fatty matter is absolutely necessary to counteract the friction caused by these impurities.

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The author has tried all the oils in common use, together with most of the patent compositions, for the purpose of preventing priming. He has always succeeded in the object sought, but has found them all impracticable when used in large quantities, or constantly applied to a boiler. The only exception to this rule has been the application of petroleum. The purest rectified petroleum has not only prevented all priming, but has prevented corrosion and removed incrustations arising both from organic and inorganic impurities, and from oxidation of metals as regards the interior of the boilers, as well as of the engines themselves. It would, indeed, appear that by using sufficient petroleum to lubricate the steam globules as they are generated, the preservation of the steam boiler and engine is insured so far as their interiors are concerned. The author has not found that petroleum, pumped into the boilers with the feed-water, has had any injurious effect on indiarubber valves in or about the air pumps, though he has used it in large quantities for several months in succession. In the feed pumps, however, where petroleum, nearly in its pure state, comes in direct contact with the valves, indiarubber cannot be used for them. The advantages attained by the use of sufficient petroleum to prevent the priming of steam boilers have been found by the author to be :—

(1) The prevention of priming, or, in other words, preventing large bodies of water from passing over with the volume of steam from the boiler to the engine.

(2) The prevention of the injurious effects produced by water passing with the steam into the cylinders of the engine.

(3) A great reduction in the quantity of feed-water necessary to produce the required volume of steam, or, in other words, an augmented boiler steaming power in proportion to the smaller quantity of water required to produce the steam required, or a saving of fuel proportionate to the smaller quantity of water necessary for producing a given volume of steam, together with the reduced power required for lifting water for condensing dry steam as against that necessary for the condensation of saturated steam. To these must be added the saving of the power absorbed in overcoming the resistance of water in the ends of the cylinders when working with saturated steam.

(4) Augmented boiler steaming power when working with injection condenser, by the total absence of incrustation or corrosion.

(5) Prevention of rust, and corrosion on the interior of the engine, together with the advantage of keeping the interiors of surface condensers perfectly clean without any other help.

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(6) Its instantaneous action on any disturbance in the water in the boilers, which is one of its greatest advantages.

(7) The increased durability of both boiler and engines.

The disadvantage of using petroleum in an engine-room—for there is one disadvantage—is, that petroleum is a combustible article which requires care in use. It ignites at a lower temperature than common oils, but with ordinary care, and keeping it out of contact with cotton or woollen stuffs, the danger of its use in engine-rooms is reduced to the same extent as that of its use in dwellings. It is, indeed, reduced to a far greater extent when it is stored in a fixed iron tank with but one opening on top for filling and connecting a suction pipe to the feed-pump of the engine. The danger is then reduced to the bringing of it to the tank. Petroleum will not ignite or burn in a closed vessel; a bar of red-hot iron inserted into a closed cistern full of petroleum will not ignite, because there is not sufficient atmospheric air for combustion. The author knows of no other danger or disadvantage in its use, and when this one disadvantage is put against the many advantages, and when it is considered that its use prevents marine engines from becoming paralysed, as but too often is the case at most critical moments, no practical engineer will, it is thought, differ from the author in the opinion that it will be wise to promote its general use.

In applying petroleum to boilers the author has constructed a combined valve and cock, as shown at Fig. 1 in the drawing. This contrivance is screwed into the valve-box of the feed-pump, between the suction and delivery valves, the safety cistern shown at Fig. 2, containing the petroleum, being placed in a convenient part of the engine-room. As the connection pipe A is inserted through the top of the cistern, while no other cocks or connections on cisterns are allowed, no danger can ever arise from inadvertence on the part of the men in the engine-room. This valve and cock is all that is required in addition to what is generally found in well-constructed steam engines—namely, a cock on the suction pipe, or a screw on the top of the suction valve of the feed-pump, one of these being required for regulating the flow of water to the pump necessary for generating the volume of steam required, and the prevention of waste of petroleum, since any overplus of water the pump takes, and which does not pass into the boiler, is returned through the safety-valve on the pump. The author has in practice regulated the water flow to the pump, so as to approach as nearly as possible the consumption in the boilers, leaving the feed cocks full open. This has given two advantages: first, no petroleum

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was wasted; and, secondly, it has directly shown when the steam was taking an undue quantity of water with it. That it is in the boiler itself that priming must be prevented appears evident, and it is equally evident to the author that all the mechanical devices for the purpose of preventing it have, for the want of the proper knowledge of the cause of priming, signally failed. Some of these devices—the superheater, for example, which is still in general use—are very complicated, and consequently very expensive.

The valve and cock applied to insure instantaneous action must have the necessary dimensions in proportion to heating surface in boilers it is intended to supply with petroleum. On starting the engines, or when forcing the fires, priming is generally most violent, and at such times the engineer's immediate attention is necessary, and he will act wisely in giving his boilers a little petroleum previous to forcing the fires. On a voyage from Copenhagen to St. Petersburg and back, with his Danish Majesty's steam yacht 'Slesvig,' last summer, nearly one hundred and forty-four hours' steaming, the author consumed nearly 40 gallons of petroleum, and this gave a gain of 25 tons of coal, as compared with what the same boilers and engines had previously consumed on the same journey in about an equal number of hours, namely 150 instead of 175 tons of coal. The ship, however, was drawing 2 inches more water last year than formerly, which increased her immersed midship section from 219 to 224·7 square feet or $4\frac{3}{4}$ square feet nearly. There was, besides, the disadvantage of being in company with a screw frigate, whose sailing powers far exceed, in speed, the 'Slesvig's' steaming powers, so that the author was constantly either forcing or easing the engines to keep in position with the frigate, which caused a considerable waste of fuel. The 'Slesvig' has a pair of Robert Napier's old-fashioned side-lever engines, with open condensers, and of 240 nominal horse-power, but which the author is now enabled to work up to 620 indicated horse-power. With the same draught of water as now, about 9 feet 4 inches, her speed formerly never exceeded $10\frac{1}{4}$ knots, and this speed was with difficulty maintained for any length of time, for the want of sufficient steam. Since the application of petroleum to the boilers, however, the speed has been increased to 11 knots; and this, without any increase in the consumption of coal. The steaming power of the boilers has been increased so much that there is now more steam than the engines consume, while the engines themselves are working with less noise than formerly.

The author succeeded last summer in removing all corrosion

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and incrustation from the interior of the Slesvig's boilers, and they are now as clean as when they left the boiler-maker's hands ten years ago. Petroleum dissolves both the lime incrustations and prevents rust corrosions when under steam pressure, while all the dissolved muddy matter can be blown out from the bottom of the boiler with the ordinary blow-off cock; the boiler requires no other cleaning out, and consequently there are no stoppages for this purpose. It may be interesting if, before concluding his paper, the author places on record a circumstance which came under his observation last year respecting marine boilers, in connection with surface condensers and the use of mineral oils.

When the surface condenser was introduced in connection with marine engines, one of the advantages expected to be derived from it was the freeing boilers from incrustation, and thus increasing the evaporating powers of the boilers; the danger of collapse arising from overheated fire-box plates was to be removed. The surface condenser was intended to return to the boiler the water taken therefrom in the form of steam, and as this water could contain no organic or inorganic or earthy particles, it was very natural to suppose that no incrustation could be formed in boilers supplied with them. But one of the first discoveries made after the introduction of the surface condenser was that the boilers supplied from it then corroded to an alarming extent, so that in many instances such boilers were entirely destroyed after only two years' service. This circumstance prevented their coming into general use until about twelve or fourteen years ago, when it was discovered that the corrosive action was caused by metallic particles taken from the interior of the engine by the steam, on its passage through it, and carried into the boiler, where they produced a galvanic action, which oxidized the plates of the boiler. About the same time it was also discovered that sea water contained the best non-conducting agent for preventing a galvanic action in the interior of the boilers, namely, its organic and inorganic contents. In fact, the same matters which had hitherto caused incrustations were now found necessary, in smaller quantities, to protect the boilers against oxidation. This protection is afforded by changing the water in the boiler occasionally with water direct from the sea, which leaves a coating of its organic and inorganic contents on the interior surfaces of the boiler, and thereby ensures safety from galvanic action, and permits the general use of the surface condenser with marine engines. We have, however, for several years past, heard of the collapsing of fire-box plates where they have been in connection with surface

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condensers, and the opinion invariably given as to the cause of these accidents has been that there was either a want of strength in the construction to assist the steam pressure, or that there had been carelessness on the part of the attendants in not supplying the boiler with sufficient water. This, however, is a great mistake, as there are other causes equally as active in causing fire-box plates to collapse as those just named. One special cause came under the author's observation. About Midsummer last year the screw steamship 'Conatio,' of Flensborg, on her way from Cronstadt to an English port, was towed into Copenhagen harbour in a disabled state. The four fire-boxes of the boiler had collapsed. They appeared to have all given way at about the same time. The fireman, on opening the fire-doors, saw the crowns of the fire-boxes sinking, and the engineer immediately opened the smoke-box doors, and took other precautions for reducing the steam pressure, and thereby in all probability saved his own life and the lives of the rest of the engine-room crew. Upon reaching the port the boilers were examined. There was plenty of water in them, and everything else appeared to be in perfect order; yet, on emptying the boiler, the injured crown plates of all four fire-boxes afforded clear evidence of overheating—in fact, they had been red hot, and this notwithstanding that there had been plenty of water in the boiler, and that there was but a trifling deposit. The only reasonable conjecture as to the cause of the accident was that on the collapsed plates was found a thin layer of ordinary boiler incrustation, not more than a twelfth of an inch thick, mixed with a dark substance, which proved on examination to be the insoluble residue of a mineral oil, which had been used for the purpose of lubricating the interior of the engines. The lubricator used was fixed on the side jacket of the high-pressure cylinder, and from thence the oil passed through the surface condenser to the boiler. This insoluble matter then mixed with the slight incrustation, and which, thin as it was, had been sufficient to make a perfectly impervious coating, which had prevented the contact of the water with the iron plates. Hence the overheating and collapsing of the crowns of the fire-boxes.

In the month of September last the author was requested by the Danish Board of Trade to survey and report upon the condition of a boiler on board a merchant steamship, the 'Bergen Huus,' of Copenhagen. This vessel came into port at Copenhagen with a boiler which had been disabled on the voyage from Norway to Stettin. Here was a similar case to that of the 'Conatio,' only perhaps a little more decisive as regards the

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cause of the accident. The 'Bergen Huus' is fitted with compound engines, supplied with steam from a cylindrical boiler, having two cylindrical fire-boxes in it, one of which collapsed. The fire-box collapsed 8 inches in towards its centre, over a length of 4 feet 6 inches from the back end, not, as might be supposed, along a line drawn perpendicularly through its centre, but at an angle of 45 deg. with it towards the side of the ship. In this case the engineer, seeing there was no want of water in the boiler, ordered the fire to be drawn out of the collapsed fire-box, and proceeded with the other fire on his voyage, and came in to Copenhagen some twenty hours afterwards. Such a piece of dangerous stupidity succeeded in his case, but has probably failed in too many others under such circumstances.

On examining the interior of this boiler the author found that half of it—namely, that side on which the feed-cock was fixed—was coated with a substance resembling black varnish or coal tar, having a thickness of about three-sixteenths of an inch, and being perfectly impervious to water. This deposit had the appearance of having been laid on with a brush, so equally was it spread, particularly over the fire-box. It was under this coating of impervious matter the fire-box plate had collapsed, while the other fire-box remained uninjured, notwithstanding that it had a coat of ordinary boiler incrustation $\frac{1}{4}$ inch thick. The incrustation on this side retained its ordinary grey colour. On inquiring of the engineer from whence this black substance came, he stated that it was produced from the oil used to lubricate the slide valves with. He observed that he was obliged to use a great deal of the oil to keep the valves from making a noise and cutting their faces. The oil used for this purpose was a half-crude mineral oil, which still retained so much of its original earthy bituminous constituents, that the latter, combining together with the organic and inorganic matter contained in the boiler, made a perfectly impervious cement, which had prevented the contact of the water and iron, and being a bad conductor of heat, caused the iron to be overheated, and thereby weakened, the steam pressure causing the collapse. The author laid a piece of this compound on a piece of iron heated to a little over red heat, which had, however, produced no further effect than the burning of a little of the bituminous matter out of it. The collapsed plate bore evidence of having been overheated, and it was only owing to the superior quality of the iron, of which the fire-boxes here, as well as in the case of the 'Conatio,' were constructed, that a most serious loss of life had not taken place.

The reason why only one half of the boiler was coated with

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the bituminous matter, the author attributes to the circumstance that the injured side of the boiler had on it the feed-cock, and that as the oil, passing through the latter, came first in contact with the incrustation on that half, it was absorbed before it could reach the other side of the boiler. The uninjured fire-box, however, was coated with an incrustation ¼ inch thick over the whole of it. Now this thickness of incrustation ought never to be found in a boiler which is in connection with a surface condenser, and the fact of its being there clearly afforded evidence of the engineer's ignorance both of the use of the surface condenser and of the meaning of a trifling incrustation to preserve his boiler from galvanic action and oxidation. But, as seen in the case of the 'Conatio,' the danger is not dependent alone upon the thickness of the coating of incrustation, but chiefly on its porosity. Let the incrustation be never so thin, if a bituminous substance is added to it which binds it together so that it becomes elastic and impervious to water, the iron plate will overheat and collapse under pressure. Hence, wherever oils containing bituminous matter are allowed to pass into a boiler, it is only a question of time as to when the incrustation becomes impervious, and the fire-box under it collapses.

The author was much surprised that the uninjured fire-box in the 'Bergen Huus' boiler had not collapsed also, more particularly as the incrustation on it was spread very evenly and closely. In boilers working in connection with open injector condensers, incrustation attains a considerable thickness in places where it cannot easily fall off. But on a cylindrical fire-box it would undoubtedly never have laid so compactly as was the case here; it would have been broken and in uneven patches. It appeared evident that some of the oil had also reached the uninjured side of the boiler, and had acted on the incrustation there. The author, therefore, would recommend precautions being taken so as not to allow these oils to enter steam boilers. There is no necessity for their use at all; a little pure rectified petroleum pumped with the feed-water into the boiler will prevent such accidents as the collapsing of fire-boxes. It will be sufficient to lubricate the internal parts of the engines, and, at the same time, will keep the surface condensers perfectly clean.

Looking at the foregoing facts, the author thinks it will not be difficult to account for the disappearance of many missing steam-ships. At any rate, a careful investigation into the cause of this class of accidents is a matter of the greatest importance, and the author hopes the remarks he has made may have the effect of drawing attention to the subject.

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DISCUSSION.

Mr. W. SCHÖNHEYDER said that the real cause of priming in steam boilers was faulty construction. If boilers, even at sea, when working with high pressures, primed to the extent assumed in the paper, it would be quite impossible to work them as economically as was now done. Some of our best makers produced compound engines which only used about 2 lbs. of coal per indicated horse-power per hour. If the boilers primed to the extent represented, that economical result could not be attained. He agreed that priming was caused, to a certain extent, through the friction of the bubbles of steam through the water, but one of the reasons was simply that there was not room enough for them to get up through the surface of the water. If boilers were constructed with a sufficiently large surface for water and sufficient steam-room, and if the steam was not drawn through a very small opening too near the surface of the water, three great reasons of priming would be removed. Dirt of course added very much to the probability of priming. If injected petroleum was such a good remedy for badly constructed boilers, its application was a very valuable invention, for there were many badly constructed boilers. The use of petroleum might also enable boilers to be used in very contracted spaces. One reason why boilers working with high pressures primed more than those working with lower pressures was their construction. Low-pressure boilers were box-shaped with upright sides, and the surface of water was large in proportion to the size of the boiler. The cost of using petroleum appeared to be very small as compared with the coal saved. He did not quite know what kind of petroleum the author recommended.

Mr. P. JENSEN said that pure rectified petroleum was to be used.

Mr. SCHÖNHEYDER said with reference to boiler plates coming down, about six years ago he met with an instance in which the boiler was worked at high pressure, and the steam exhausted from the engine was allowed to heat the feed-water. A large quantity of grease was allowed to go into the water. A new fire-box was put in, and the engine was worked precisely in the same manner, the cause of the boiler failing not being suspected. It only worked a fortnight before the plate came down again, although everything was good and well made. When the boiler was again repaired, the steam was kept from the feed-water, and the boiler had worked well ever since. At some works of which he had lately had charge, about four-fifths of

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the steam was condensed in the pipes, and the heat was used for heating and drying in the factory. Nearly all the grease that was used in the engine was therefore returned to the boiler. In less than twelve months one of the flue plates had sunk about an inch. He suspected the cause, and remedied it by using a large quantity of soda every day. Soda was mixed with the feed-water, and the boiler was blown out frequently. That treatment also prevented any scale from forming on the boiler. The lime in the water simply formed a muddy deposit which was blown out.

Mr. V. PENDRED said it was quite possible, improbable as it seemed, that petroleum had produced the effects stated in the paper. As a rule, petroleum contained no free oxygen. Most of the other oils used in the arts were animal oils, which contained free oxygen, which would combine with the metal of the boiler and oxidize it if put into it. He had recently seen some statements to the effect that petroleum had a remarkable effect in preserving boilers from incrustation. Mr. Schönheyder had stated that priming in the practical sense did not take place in boilers as a rule. If, however, they used the word "priming" in a slightly different sense, all boilers primed. There was no boiler which did not send over a proportion of water with the steam. That proportion varied with different waters, different boilers, different systems of firing, and different modes of construction and arrangement of the steam pipes. Cornish boilers were found on experiment to prime from 5 to 12 per cent. Locomotive boilers, probably, primed a little more or a little less. The object of the author was to prove that priming was the result of the friction of the globules of steam carrying the water away with them, and in order to prevent that friction he practised the exceedingly subtle operation of lubricating the globules of water.

Mr. JENSEN: The globules of steam.

Mr. PENDRED said that he had never seen a globule of steam, and he hardly understood how steam could be lubricated. He should say that the water was lubricated, and that the steam passed over the lubricated surface as a railway wheel passed over a greased rail. But although lubrication had been found to answer in marine boilers, it would not answer in other boilers. The old practice of putting tallow into marine boilers was well known. In locomotive boilers lubrication would not answer. The contents of a single oil-can in a locomotive boiler would cause the boiler to throw out all its water. Hence lubrication answered in one case and not in another, and that required explanation. Another point raised by Mr. Schönheyder was that as long as there was sufficient water surface in

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a boiler they would not have priming. The question was not one of surface, but it was a question of where the surface was provided. In Cornish boilers, and externally fired boilers, they could get a very large water surface, and they could make all those boilers prime; at the same time, some boilers with a very contracted water surface would not prime. That was the case with the Root boiler, which might be taken as the type of a boiler with about the most contracted water-way possible. He had tested that boiler for priming, and he found that the priming did not amount, in the maximum, to more than about 12 per cent., which was much the same as in a Cornish boiler, although the water surface was not one-tenth of what it would be in a Cornish boiler. It had been recently said that, if they wanted to get rid of priming, all that they had to do was to wash their steam. That statement would scarcely bear out the author's theory, but he (Mr. Pendred) knew of a boiler on board a yacht on the river Clyde which was notorious for priming, and in which the practice of washing the steam had been tried with considerable success. That boiler delivered steam from a small dome on the top. There was a hole about six or seven inches in diameter between the dome and the boiler. That was not used as a manhole, and the steam pipe came down from the inside of the dome, went along the top of the boiler, and came over to the engine. It was impossible to get any speed out of the boat, or to keep any water in the boiler, especially when the vessel was going out of fresh into salt water. A perforated plate was tried, and the priming was worse than before. The owner of the yacht left the dome where it was, and put on the top a kind of separator. He had the means of drawing the water out of the separator, but he found that the separator produced no alteration whatever. The separator filled up with priming water. Then he took a pipe from the top of the boiler and carried it down so that the end dipped under water in the separator, and that steam pipe was taken from above this water level. The result was that, as soon as the engines were started, the separator primed half full almost at once, as shown by a glass gauge. After that, the separator never appeared to get fuller. The water could be drawn off from it if necessary, but it appeared to fill so far and no farther, and the steam bubbled up through the water, and the owner had no more trouble from priming. He (Mr. Pendred) had had some experience of boilers in which the steam was carried up through a contracted water-way, and in all such cases, supposing there was an inclined tube delivering into a narrow water chamber at the end, if the steam was taken straight off

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from the top there would doubtless be priming. But it was not absolutely necessary that there should be priming with a contracted water-way, and, in fact, it had been found that the longer the column of water from which the steam had to rise in such a case, the better and dryer would the steam be. In the case of the 'Serapis,' which had been mentioned as having a wooden deck put in her boilers, it was to be remembered that that vessel, although she made only nine knots until she arrived at Malta, yet, after she got to Malta, kept very good time, and did the rest of her voyage without any great difficulty from priming. The conclusion which he (Mr. Pendred) had come to with regard to priming was that if sufficient surface was provided in the proper place, and if the boiler was not pressed too much locally, and if proper precautions were taken for drawing off the steam from a sufficiently diffused surface, and if, in some part of the boiler, a quiet place was provided where no ebullition was going on, and where there was a downward current, there would be no such thing as priming. If, on the contrary, a boiler was made so that the water was continually "lifting" because the steam was continually struggling to fight its way up, the boiler would be certain to prime.

Mr. SCHÖNHEYDER said that he supposed that there was a drain pipe in the case which Mr. Pendred had been describing.

Mr. PENDRED said that there was no drain pipe into the other part of the boiler. There was a drain pipe into the ash-pit.

Mr. SCHÖNHEYDER said that the priming must still take place into the box, and unless the water was drawn away again the boiler would prime.

Mr. PENDRED said that there did not appear to be any continual drawing away of the water, so far as he knew. An American boiler of that type, which was a notorious primer, was cured by taking out two rows of tubes and putting in two plates, and it appeared from that that there was a continual current produced.

Mr. SCHÖNHEYDER said that he meant to say that the want of surface was only one of the causes of priming in many boilers. He was quite aware that there were many other causes.

Mr. W. J. PRIM said he knew a somewhat similar case to that stated by Mr. Pendred, in which priming had been cured by putting vertical tubes into the flues similar to the Galloway tubes. That clearly showed that the space between the tubes which ran parallel through from end to end of the boiler, as in the case of Lancashire or double-flued boilers, was too contracted. The alteration got rid of the priming at once. With

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regard to the petroleum-arrangement, he was afraid it would require a greater number of fittings than the author of the paper represented. Engineers at sea would be anxious to know what quantity of petroleum they had in the tank, and they would naturally desire to fix a gauge to it; but that gauge would be a source of danger if the glass got broken.

Mr. H. CONRADI asked whether any experiments had been made in the application of the petroleum apparatus to ordinary land boilers or portable engines. As far as he could see, the application of petroleum appeared to be exactly the same as that of fat or greasy substances which had been applied for the purpose of preventing ebullition. The motion of the water due to the steam passing through it must necessarily throw particles of the water up if the boiler was badly constructed, and did not afford sufficient space for the steam to settle quietly above the surface of the water. But in most cases in land boilers domes were provided to allow the steam to settle and dry and to pass through without taking the water with it. He did not think the friction of the steam caused the water to escape. He believed the contrary.

Mr. F. W. HARTLEY said it would have been satisfactory if the author had given the specific gravity of the petroleum, because without that they could not know what was meant. He thought that a small quantity of petroleum injected into a boiler would immediately be volatilized by the heat. Distilled petroleum, which had a specific gravity of from 650 to 680, was, under ordinary temperatures, so volatile that it passed off rapidly as vapour when air was projected through it. He apprehended that in steam boilers it would be volatilized immediately after it had been injected, and therefore there would be no petroleum in the water.

Mr. P. JENSEN said that he would give some particulars of experiments with land boilers which he had received since Mr. Major's paper was written. He had a letter from a gentleman in Copenhagen, who had used the apparatus and pure rectified petroleum for land boilers. The writer said: "The boilers in my factory have constantly troubled us with incrustations, caused by the water which we are obliged to use being highly charged with earthy particles, and whenever we opened these boilers, which we did very frequently, we found the incrustations increased in thickness, and which took much time and trouble to remove by hammering it off again by hand; several times overheating of the fire-box plates have taken place and caused the plates to collapse, causing me much annoyance with stoppages, besides heavy expensive repairs."

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An analysis of the water shows the following:

PARTS CONTAINED IN 10,000 QUARTS OF WATER.

Soluble matter	·78 parts.
Insoluble	5·40 „
	6·18 „

The same quantity of water contained

Carbonate of lime	2·66 parts.
Carbonate of magnesia	·59 „
Sulphate of lime	1·34 „
Less definitely separated matters	·81 „
	5·40 „

Having tried many other means which proved ineffectual, he accepted Mr. Major's offer to cure the evil.

"One of the boilers," he says, "is from 1864, with a heating surface of 420 feet, or about 30 horse-power, working with a steam pressure of 45 lbs. The other boiler is new, and was first taken in use in the latter part of 1876, having a heating surface of 957 square feet (or about 10 horse-power), working at a pressure of 65 lbs. per square inch.

"Both these boilers were in daily use from the 1st of January until the 1st of February, 1877, when we opened them. The results were that we found not only the new boiler perfectly clean and without a particle of incrustation, with the exception of a trifling quantity of muddy matter lying on the bottom, but the twelve years' old boiler had also been cleaned of all its old incrustations, with the exception of a few patches here and there on its sides and in the 'Galloway' tubes; indeed, the boilers had the appearance of having been in use but a few hours instead of a month. Mr. Major has achieved this by means of a simple apparatus, invented by him, whereby he forces petroleum into the boilers together with the feed water. In the largest of these two boilers we have used a little less than a gallon of petroleum per day, while the smaller boiler has had only two quarts of petroleum per day, and that only during the last eighteen days of the month; to this smaller quantity and shorter time we may probably attribute that a little of the old incrustations still remained in the boiler."

That would be an answer to Mr. Hartley, for whether the quantity pumped in went away quickly with the steam globules and into the steam space, or kept in the boiler a long time, was, after all, a question of minor importance. The question was, Did the petroleum cure the evil?

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Mr. CONRADI remarked that that letter proved, as he had expected, that the effect of the application of petroleum was rather to dissolve the limes, chalk, and incrustation than to prevent the priming, and that the priming therefore was the result of bad construction, and could be obviated by correct construction better than by the application of any greasy matter.

Mr. SCHÖNHEYDER, in confirmation of what Mr. Pendred had stated as to pure water causing priming, said that no one used purer water than those who worked Perkins's boilers. He had seen one of those boilers at work lately, and it primed violently. Mr. Perkins said that he did not make steam in the ordinary manner, but he made foam.

Mr. V. PENDRED said that Mr. Perkins had told him the same thing, and had stated that his was not a boiler, but an apparatus for making steam. So long as he got steam, he did not care about the foam. He worked at a pressure of from 300 lbs. to 600 lbs. per square inch.

Mr. JENSEN, in replying to the discussion on behalf of the author of the paper, said that a question had been raised as to the influence of having a large surface of water and large spaces for the steam globules to escape. It was very well to say that there ought to be large surfaces of water and large water spaces, but the fact was that they could not always be got. That being the case with high-pressure steam boilers as they were now constructed, the question was what they were to do with the contracted spaces and with the contracted water surfaces which had now become a necessity. And that question he thought had been solved by the author's method, for boilers otherwise of the most incurable kind had been cured. The case mentioned by Mr. Schönheyder, in which the collapse of a fire-box took place in a fortnight in consequence of the use of feed water which had been heated with the exhaust steam, clearly corroborated the statement in the paper. Mr. Schönheyder had mentioned soda as a remedy. It was a very nice remedy if pure, but the soda of commerce was not pure, and if used in large quantities it would eat the boilers away inside. The statement made by Mr. Pendred that petroleum did not contain any free oxygen was very interesting, but the objection raised by him as to the two boilers named in the paper was not to the point. It was perfectly true that in those two cases mineral oil was used, but it was a crude or heavy oil, such as Crane's oil, and contained a great deal of bituminous matter. Such oil if put into the engine passed through it and the condenser, and a great part of it ultimately went into the boiler, which might become so coated

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with the thick oil as to be in a very dangerous condition. Mr. Major regarded Crane's oil as dangerous to the boiler, although it was very useful for lubricating the internal parts of the engine. Pure rectified petroleum contained all the good qualities of Crane's oil, in so far that it lubricated the engine and kept the condenser clean, and it had the additional advantage of not choking up the boiler, as Crane's oil did, according to Mr. Major's statement. If, as Mr. Pendred said, most boilers primed, that fact was the best apology for the present paper. If it was only a question of degree, some boilers, as Mr. Pendred said, priming 5 per cent. and some 20 or 30 per cent., he (Mr. Jensen) thought it was good to have found a remedy.

The case of locomotive boilers was a very peculiar one, since even a very little tallow would sometimes produce priming, and that which stopped priming in other boilers actually, under certain circumstances, caused it in locomotives. He would state what he believed to be a cause of it in the words of Mr. Major: "All oils commonly used for lubricating steam engines contain either resinous or gummy substances, or if mineral oils imperfectly distilled, then they contain bituminous substances which are insoluble in water. Vegetable and animal oils are all purified by means of acids. When any of these oils are admitted into the boiler of a locomotive, which it must be remembered contains a smaller quantity of water in proportion to the heating surfaces around it than any of our generally used steam boilers, then the fatty particles of the oil are immediately evaporated or separated from the insoluble particles of it. The former go away and, with the volume of steam, pass off into the steam-chest, while the insoluble particles remain in the water together with the acids which they may contain, and those acids dissolve the particles of incrustation if there are such in the boiler, and thereby increase the insoluble matters in suspense in the water, and in sufficient quantities to cause an undue friction on the surface of the steam globules which have to pass through the water. As soon as the water in the boiler is brought into this state, it is instantly put into violent motion, and particles of it are carried together with the steam into the engine, or, in other words, priming commences."

The author went on to mention the statement of an experienced locomotive superintendent, who told him that a few drops of dirty oil passing through the safety valve when the engine driver greased his safety-valve lever-joints was sufficient to set the water in the boiler in violent motion as soon as steam was got up. With a locomotive boiler, which was perfectly free from incrustations, the case was different. The pure rectified

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petroleum would then not have any incrustation to act upon in the same manner, as in the case of the other oils he had mentioned. As a matter of fact, Mr. Major had also found that petroleum as applied to locomotive boilers checked priming. One speaker (Mr. Prim) said he thought that other fittings must be necessary besides those which were shown in the diagram; but in fact, the tank made exactly according to it and like the one exhibited, had been used for many months and no gauge or other fittings had been found requisite. A certain quantity of petroleum was put in every watch—that was every four hours. He could not reply satisfactorily to the very curious statement about Perkins's boiler, but it had struck him that if Perkins used perfectly pure distilled water, such water, which was a solvent, might eat away the internal parts of the boiler, and he had heard that it had that effect, in other cases at all events. The frothy appearance of the water might be due to part of the iron being actually oxidized and mixed with the water.

Mr. SHÖNHEYDER mentioned that Mr. Perkins had taken his boiler to pieces, after thirteen years' wear with distilled water, and had found no eating away whatever.

Mr. JENSEN said that the pressure in the case of that boiler was quite exceptional, but the statement was a very curious one.

The PRESIDENT, in closing the discussion, said that priming was a contingency to which all boilers were subject, but it appeared that they could not quite get at the exact cause of the phenomenon. It had been attributed in a great measure to want of space in the boiler. Boilers had generally to be put up in a circumscribed space, and therefore it was impossible to prevent priming if caused by want of space. Priming appeared to take place in all boilers, but not to the extent which the paper might lead one to suppose. Before petroleum could be accepted as an universal remedy, more facts were necessary than had been brought forward in the paper. Many individual cases of priming had been cured by peculiarly ingenious arrangements which were not susceptible of universal application. No doubt each boiler admitted of separate treatment; and it would be impossible to imply that what had answered well in one boiler under certain circumstances would certainly act as a remedy for a different boiler under different circumstances. The paper had introduced an important subject, for priming was a constant evil and caused a great deal of misunderstanding between boiler makers and boiler users. Petroleum had not been tried to a sufficient extent to make it certain that it would

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answer in all cases, but still it had been tried to a certain extent, and every method must have a beginning. Any remedy which had a fair chance of curing the evil ought to receive consideration from engineers. A question had been raised as to the volatilization of petroleum. It was quite possible although petroleum was so light, that it would be readily volatilized in the boiler, yet in passing off in the form of vapour it might remedy the evil complained of. That was a question which was open for further consideration, and must be solved by further experiment, which was really the only true way of arriving at a definite conclusion on such subjects.

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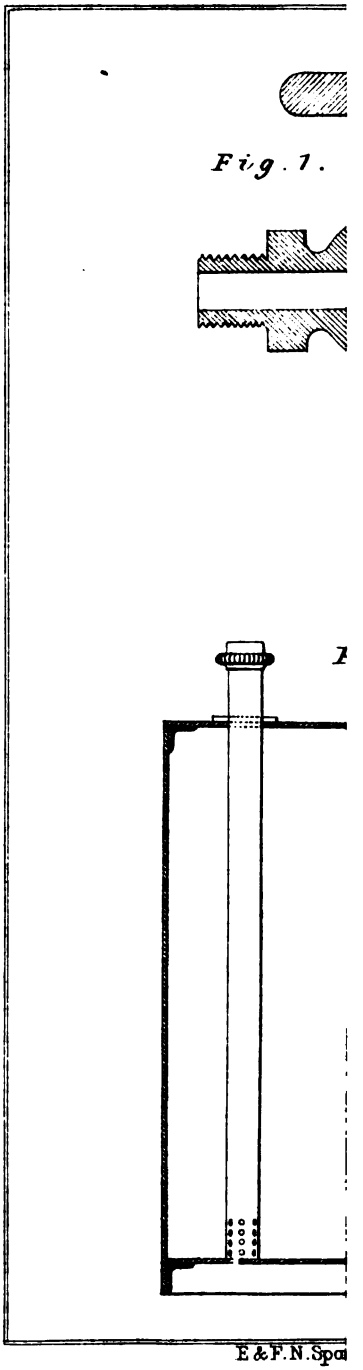

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May 7th, 1877.

THOMAS CARGILL, PRESIDENT, IN THE CHAIR.

DIRECT-ACTING PUMPING ENGINES.

By PHILIP BJÖRLING.

The author's intention was to have given a general and comprehensive history of the direct-acting pumping engines, from its origin up to the present time, but the President and several Members of this Society having advocated short papers, he proposes on the present occasion to confine himself to the consideration of a few types only.

During the last few years a great many designs of direct-acting pumping engines, possessing greater or less merit, have been patented, all of which carry the steam the full length of the stroke. Some are worked by steam-moved valves wholly, and some aided by tappets, or other mechanical arrangements, actuated from the main piston-rod. The most important and successful of this class are the "Special" and the "Universal" steam pumps. The former being worked by means of tappets in the cylinder covers, and the latter by valves moved by steam only; both are American inventions. Blake's steam pump is worked by a combination of tappets and steam-moved slide, but without any governing arrangement. The next and more important type of pump, and one which is now fast making headway, is the automatic expansive class. This class will be presently fully considered.

In 1857 Mr. William E. Newton took out a patent for an engine, in which the steam was admitted into the main cylinder by means of a stationary supplementary cylinder, and reversed by means of a lever arrangement from the piston-rod actuating a small supplementary slide-valve inside the valve chest, but this engine was not fitted with any governing gear or cataract.

About the year 1862 Mr. Haswell made an attempt in this direction by bringing out a direct-acting engine for working two press pumps, one at either end of the cylinder. This engine was manufactured at the Kirkstall forge, near Leeds. It was fitted with a supplementary cylinder, working the main slide-

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valve, and had a cataract governing its speed, but Mr. Haswell made no attempt to cut off the steam automatically. The supplementary piston was reversed a little before the end of the travel of the main piston, by means of levers and tappets actuating a small slide-valve. After Mr. Haswell came Mr. Henry Davey with his ingenious "Differential" gear, which has been already described before the Society, and is too well known to require any comment. Lastly comes Messrs. Cope and Maxwell's self-governing engine, in which the steam is cut off automatically. The author will now proceed to describe three different direct-acting pumping engines, leaving for some future occasion the description of other types.

The "Universal" short-stroke pumping engine, which has been so successfully applied for a variety of purposes, such as for draining mines, working hydraulic-press pumps, raising wrecks, emptying docks, and a variety of other work. This pumping engine is well known to engineers, as far as the outward appearance goes, but very few, comparatively speaking, seem to understand its internal arrangement. As before stated, the valve is steam-moved, not worked by means of levers, tappets, or cocks, and the gear must therefore be simple, durable, and not likely to get out of order. Fig. 1 is a sectional elevation; Fig. 2, a plan; Fig. 3, section through exhaust port; Fig. 4, section through the shooting or valve-moving parts.

It will be seen that the steam cylinder is a plain barrel, with a steam branch on one side and an exhaust branch on the other. The piston, which performs the functions of a valve in opening and closing the ports and steam passages, is as much longer than the stroke as is required to cover the steam ports at each end and centre of the cylinder alternately when working. Inside this piston is a smaller piston or steam-moved valve, which is actuated by the steam. A represents the steam-cylinder, provided with covers at each end; B, the piston; C, the piston or steam-moved valve; D represents the steam branch, and E the exhaust branch; F F, rods connecting the piston covers G G; H, ordinary packing rings surrounding the ends of the piston; I is a guide pin, working in a corresponding groove to prevent the piston from rotating in its reciprocating movements; J is a pin, working in a groove, to prevent the steam-moved valve from turning round; K is the piston-rod connecting the steam piston with the pump piston.

The action of the steam in the cylinder and the working of the piston is as follows: steam enters at the inlet pipe D, Figs. 2 and 4, and has constant access to the interior of the piston through the aperture L and elongated slot M, in the

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side of the piston; it also enters the interior of the steam-moved valve through the rectangular openings marked N, which are in constant communication with the inlet pipe. This aperture is made above the centre of the steam-moved valve in order that the steam may exert a pressure downwards greater than in any other direction, and thereby cause the bottom surface of the piston valve or steam-moved valve to work steam tight, more particularly on the face where all the ports are. The steam passes down the port O, and thereby has access to one end of the piston, causing it to make a stroke. Near the termination of the stroke the piston causes the elongated slot P, in its side to pass over the opening Q, in the side of the cylinder, which communicates by a passage to the opening R which is made sufficiently long to enable the orifice of the passage leading to the back of the steam-moved valve to be in constant communication with the orifice Q, as it passes along over it during the completion of the stroke of the piston, over which passes simultaneously with the latter an orifice and passage S, in the piston, leading direct to the inner chamber wherein the piston valve works. The steam consequently obtains access to one end of the piston valve and forces it to the opposite end of its traverse, the steam on the opposite side having at the same time free access to the exhaust branch E, through the port T in the piston, similar to the port S before mentioned, and which passes over a corresponding aperture U, in the centre of the length of the cylinder. The piston valve C thereby, on the principle of the D slide, changes the direction of the steam, at the same time opening the exhaust, causing the piston to make a return stroke, the steam escaping down through the aperture and out through the exhaust branch E. A certain amount of lead is given to allow the steam to exhaust before the entrance of steam on the other side, which is accomplished by permitting the passage V to communicate with each exhaust passage leading to the back of the piston valve a little before the slot P covers the aperture Q, which allows steam to enter the opposite end. By this arrangement an alternate movement is given to the piston valve, and thus causes the piston to reciprocate to and fro.

A great many engines on the above principle have been working continuously for the last seven years, giving most satisfactory results. One pair particularly may be mentioned, which have now been at work over two years under most trying circumstances. The cylinders are 21 inches diameter, and have 10-inch double-acting ram pumps; they are attached to twenty 3-inch tube wells which are 24 feet deep and 25 feet

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apart, at an average horizontal length of 500 feet suction pipe. They deliver the water into a tank 120 feet high.

The author will next notice a slight modification of the "Universal" short-stroke valve gear, which enables the engine to work vertically. Fig. 7 is a sectional front elevation of a pump fixed in a well. Fig. 8 is a sectional side elevation, and Fig. 9 is a transverse sectional view of the same. A is the cylinder, B the piston, and C the piston valve; D is the steam branch, and E, exhaust branch; K is the piston rod connecting the piston with the pump ram. The action and working is as follows: Steam enters from the steam-pipe D, and is communicated through passages within the cylinder cover to the two independent stop valves L and M, which regulate a variable supply of steam to each end of the piston, when the work of the up-stroke is greater or less than that of the down-stroke, as, for instance, when working a single-acting pump used for a deep well, the lifting or forcing of water being done by the upstroke only, or in some cases by the down-stroke only. It is only applicable to double-acting pumps, when the weight of the piston-rod and other appendages tends to throw more power on the up-stroke than upon the down-stroke. The piston valve C is provided with a diaphragm N for the purpose of separating the two inlet steam-ports O O, and the portion B' of the piston is furnished with a longitudinal dividing rib P, which separates the steam admitted at the steam passages Q and R at opposite sides of the cylinder, and allows each to act independently of the other, the steam admitted through the stop valve M having access to the bottom of the piston, while the steam admitted from the stop valve L has access to the top side only. The stop valves L and M are provided with screws to regulate the quantity of steam to their respective sides of the piston; the action of this engine and valve gear is nearly the same as that of the "Universal" short stroke previously described.

The writer next proposes to consider the "Universal" long-stroke pumping engine. This engine is on exactly the same principle as the "Universal" short stroke, but it is slightly modified. In the "Universal" short stroke, the slide is in the main piston itself; in the long stroke arrangement it is in a piston valve outside the main cylinder, but is worked on exactly the same plan as regards motion, the main piston being one of ordinary form. The valve gear is placed on the top of the cylinder, and therefore is easy of access. This engine is naturally more economical, as it has fewer times to reverse, and consequently less number of times to fill the steam ports and

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clearances than the short stroke, to give the same number of feet piston speed per minute. But on the other hand, where very rapid action is desirable, as, for instance, for moderate lift pumps for emptying wrecks, &c., the instantaneous reversing action of the short stroke Universal possesses advantages which have never been attained by any other form.

These engines do their work admirably, and have been well spoken of by users. One of these engines—15 inches diameter of cylinder, 3 feet stroke, fitted with a 7-inch double-acting ram pump, 7 feet length of suction—is forcing water 180 feet perpendicular, with 40 lbs. of steam in boiler. It has been put down to replace a high-pressure pumping engine 50 inches diameter of cylinder, 9 feet stroke. The latter required six boilers 36 feet long, 4 feet diameter, the former only two of them. It is at work at Eckington Colliery, Chesterfield. Another is working at the Yate Collieries, near Chipping Sodbury, lifting 2500 gallons per hour up a perpendicular height of 480 feet, going 30 strokes per minute, with a steam pressure of 30 lbs.; the boilers are 340 yards from the pump.

Fig. 10 is a longitudinal section; Fig. 11, plan; Fig. 12 is a section through centre of cylinder, and Fig. 13, section of the valve gear through the ports for moving the valve. A is an ordinary cylinder, with steam and exhaust ports and exhaust branch; B, steam piston; C, piston rod; this cylinder is also furnished with valve-moving ports D D. The main steam ports are kept back and only small ports E E for the end of the stroke, and adjusting screws F F at the ends of the cylinder, the object of which is to retard the motion of the point of reversal, so that when the piston B approaches the end of its stroke it covers the main cylinder ports, thereby retarding the exhaust, and pulls the piston up gradually at the end of the stroke, and by the same means steam is admitted to the piston slowly. This causes a partial pause, which allows the pump valves to settle down on their seats without a knock or heavy blow; G is the valve chest; H, the main piston valve; I is the shooting or steam-moved valve; J, the starting handle; K, the sector; L, the valve-moving ports for the steam-moved valve; and M is the exhaust for the same; N is the steam inlet; O, the steam ports; and P, the exhaust port for the main valve H; Q is a stud for moving the steam-moved valve, by means of the starting handle J, and the sector K.

The action of this gear is as follows: Presuming steam has been turned on and the inner valve I has come to the position shown in the drawing, the main valve H is in position for moving the main piston to the right end of the cylinder; when

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the piston passes the "shooting" port D live steam enters it from behind the piston, and passes up the port L in the main piston valve, and acts on the right end of the "shooting" valve I, and moves it to the left of its chamber. During this time, the left of the "shooting" valve chamber is open to the main exhaust by the port M. By thus moving the inner or supplementary valve, the steam port in the main valve communicates with the live steam supplied to the interior of the inner valve by small openings in the side of this valve, and the exhaust cavity in the "shooting" valve is placed in communication with the main exhaust port. This position of the "shooting" valve I admits steam to the right end of the valve chest G and exhausts it from the left, and thereby causes a motion of the main piston valve H to the left, which places the port and steam passages of the main valve in position for reversing the motion of the main piston, to the left end of the cylinder, and when the piston passes the port L live steam is supplied to the left end of the "shooting" valve. In the meantime its right end is in communication with the main exhaust by the small port; the "shooting valve" is thus moved to the right, which exhausts steam from the left end, and moves the main piston valve to the right end of its chamber, and thereby places its ports and steam passages in position for reversing the motion of the main piston to the right. The shooting and main valves will thus continue to act, as long as steam is supplied, and there is no possibility of a dead point. It will be seen, that the port for the steam of the main piston valve serves also for the exhaust; these are made V shaped, so that the steam is retarded in its ingress and egress, and by that means the main piston valve is prevented from striking violently against the ends of the valve chest. The hand-starting gear is very simple, consisting of a stud Q, which is fixed in the inner valve, and a quadrant or sector K is fixed on a spindle, in such a position that the valve can work freely without touching the stud. But if the inner valve should, by any unforeseen circumstances, stop in any other position than at its extreme travel, the only thing is to move the starting handle, which is fixed on the spindle, and the sector will catch against the stud and move the inner valve to the end of its chamber. The stud Q works in a slot in the main piston valve.

The author will, in the third place, notice the self-governing engine, which has been constructed in two different forms. In one form both the cataract and valve-moving cylinders travel; and in the other, the valve-moving cylinder is stationary, and the cataract cylinder only travels. The self-governing motion

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was introduced to ensure economy of fuel, to procure a positive motion of the valves at all times, and for regulating the motion of the main piston, under all circumstances, to which pumping engines are subject by suddenly increased or diminished load on the pump or pumps, and thereby render the engine safe under variable loads, by varying the pressure of steam in the main steam cylinder or cylinders, according to the load or resistance against which the piston works. This is accomplished by actuating the main slide valve of the engine by the combined motion of a valve-moving cylinder and a valve-moving piston. The valve-moving cylinder receives its motion from the main piston of the engine by means of levers, and consequently has a motion which varies with the velocity of the main piston. The valve-moving piston is actuated by the direct pressure of steam, and has its motion controlled and rendered constant by a cataract governor. The valve-moving cylinder and valve-moving piston travel in opposite directions, the one acting upon the main valve to cause it to open the steam ports, and the other to shut off the admission of steam. The resultant of these two motions is to cause a motion of the main slide valve, which varies with every minute increase or decrease of the resistance of load upon the main piston.

Fig. 15 represents a longitudinal section; Fig. 16, plan; Fig. 17, cross section of an engine fitted with the self-governing gear and a double-acting ram pump. In this arrangement of the gear, both the valve-moving cylinder and cataract governor travel. A represents the main cylinder, provided with the usual steam and exhaust ports and passages; B, the main piston; C, the valve chest; D is the main slide valve of the ordinary D type; E is the valve spindle, which is prolonged, and also acts as the rod for the valve-moving piston F, and the cataract piston G; Q is the valve-moving cylinder, on the top of which is a small valve chest H, in which works a supplementary valve I. This valve admits steam alternately on either side of the valve-moving piston F; N is the supplementary valve spindle, which is provided with two tappets O, and on the end of this spindle provision is made for the hand-working lever, shown in plan at Fig. 16. J is a pipe admitting steam from the main valve-chest to the valve-moving cylinder chest, and K is a pipe leading from the valve-moving cylinder to the main exhaust L. These pipes work in glands, shown in plan, Fig. 16. The cataract governor P consists of a plain cylinder with a port or passage leading from one end of the cylinder to the other, and an adjusting plug is fitted in the middle of this passage for regulating the speed of the valve-moving piston,

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and consequently of the main slide valve, which is attached to the same rod. R is the main lever, working on a fulcrum S; the bottom end of this lever is, by the two links T, connected to a horn or arm U, which is fastened to the main piston rod V, with two set screws or a cotter. At the top part of the main lever, a little distance above the fulcrum, are two side links W, which connect the levers to the cataract cylinder; the top ends of these levers are prolonged, and fitted with small rollers for working the tappets O; the valve-moving and cataract cylinders are coupled together by two stays X X.

The action of this valve gear is as follows: By the position of the valve I, shown in the sectional elevation, Fig. 15, steam will be admitted to the right-hand side of the valve-moving cylinder Q, and thus move the main slide valve towards the left, and by that means admit steam into the main cylinder at the right end, consequently commence to move the main piston towards the left. But as soon as the piston commences to travel, the top part of the main levers R will also travel, but in the reverse direction, towards the right, and the valve-moving and cataract cylinders go with it, the slide valve will still move onward to the left, till the valve-moving piston F has come to the end of the valve-moving cylinder, when the main valve will be taken back by the valve-moving cylinder and cut off the steam. The rollers on the top of the main levers will strike the tappet O, before the main piston has arrived at the end of its stroke, and thus, by reversing the supplementary valve, the whole is reversed.

Assuming that the engine has commenced its stroke, and the resistance is very great, the main piston will travel on slowly, but the valve-moving piston will travel as fast as the cataract governor will allow. The main slide valve will go to the end of its stroke before the main lever has time to pull the valve-moving and cataract cylinders back, consequently cutting off the steam late. But if the reverse should occur through the load being light, the main piston will travel fast and pull the valve-moving and cataract cylinders back before the main valve has had time to travel to the end of its stroke, and therefore cut off the steam from the main piston early.

When this engine was exhibited at the Royal Agricultural Society's show, at Birmingham, last year, the delivery pipe was throttled by means of a screw-down valve until the resistance on the pump ram was so great as to nearly balance the pressure of steam in the cylinder, of course materially reducing the speed of the piston. The delivery pipe was suddenly opened by two sharp turns of the hand wheel, when the main piston

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had completed three quarters of its stroke, without any appreciable augmentation in the speed of piston to which the cataract governor was adjusted. The author thinks this was a good proof of the sensitiveness of the self-governing gear. The slide valve of this engine works in a similar manner to an eccentric-moved valve, opening and cutting off steam quick, not, as is the case in most direct-acting automatic expansive engines, with a slow motion and wire-drawing the steam.

Another great advantage in this gear is the ease with which the valves are set, almost any ordinary engine fitter can do it; so that in the case of any simple repair being required, no skilled workman specially trained to the engine is obliged to be sent for, as is so commonly the case with engines of this class. These engines can, of course, be made either high or low pressure, compound or non-compound, according to the degree of economy of fuel required, the space which can be allotted to it, and other circumstances.

In conclusion, the author will describe three different types of pumps which he thinks the best for ordinary purposes. The first is a double-acting piston pump, with leather bucket and indiarubber ball-valves, as illustrated at Figs. 1, 2, 5, and 6. Fig. 1 is a longitudinal section; Fig. 2, a plan, showing one group of suction and one of delivery valves removed; Fig. 5 is a section through the centre of one of the ball seats; Fig. 6, a section through the same place, showing ordinary gun-metal mitre valve; 1 1 are the suction, and 2 2 delivery valves; 3 is the suction, and 4 the delivery pipes. These valves have gone through seven years' experience, and are increasing in favour, they work well up to a head of 200 feet, or say 100 lbs. pressure per square inch, including friction.

The second is a double-acting ram pump, with only one barrel, and is shown in Fig. 10, which is a longitudinal section. Fig. 11, a plan, showing the indiarubber disc valve; Fig. 14, a front view of the gland and stuffing box. This pump consists of a single barrel, 1, which is provided near the centre with a stuffing box 2, for the plunger or ram 3 to work through, and each end of the barrel is in communication with a set of suction and delivery valve boxes. The valve boxes are cast in one with the barrel. The valve-box cover has an air vessel cast on it, and a communication is made between the delivery box and the air vessel; 4 is a bonnet which covers the back end of the pump, and in which the ram works.

The author now comes to the third type of pump. In cases of high lifts, it is desirable to expose the stuffing boxes of the rams, thus making them accessible, and so that it is evident at

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sight if they are packed sufficiently tight or not to prevent leakage. This is particularly the case if the pump is used to force water to a great height. In such cases the pump is made in two pieces, as shown in Figs. 15 and 16, joined together by a distance piece, or, as in the present instance, securely bolted down on a bed plate. 1 1 are the two barrels; 2 2, the gland; 3, the ram or plunger; 4 4, the suction; and 5 5, the delivery valve boxes. This class of pumps has been extensively used by Messrs. Hayward, Tyler, and Co. with great success.

The author has now brought before the members a few examples of the leading types of direct-acting pumping engines, and hopes upon a future occasion to describe other similar machines.

DISCUSSION.

Mr. H. Davey asked why the author adopted such a complicated method of producing the results which he did, and why were the steam cylinder and cataracts movable and worked in slides involving the use of telescopic pipes and stuffing boxes? It would not alter the general arrangement of the engine, and would be much more satisfactory if he were to take from the long lever B the stationary pin which now passed through the stationary casting, and fix the lever on to the piston rod of the subsidiary and cataract cylinders, instead of on to the casting, and drive his slide rod from the upper part of the lever. He would then dispense with telescopic pipes and slides and other complicated arrangements. That would greatly simplify the engine. He (Mr. Davey) did not agree with the author when he said that that engine was far simpler than any other engine of that class. The motion appeared to be obtained in an indirect manner, when all the elements were present for producing it in a simple way.

Mr. A. F. Phillips said he was surprised to hear the author state that the pumps described by him were more economical than the ordinary pumping engine which he took down at Eckington Colliery. It would be desirable that the author should state the character of the engine he removed. He (Mr. Phillips) had had considerable experience in the direct-acting pumps, known as the Special, and also with those made by Hayward, Tyler, and Co., and he had found that though convenient they were very extravagant in steam. There was no comparison between them and the horizontal or beam engine running at a high speed. Another great objection he had always found in connection with the direct-acting special pump was the noise made in working and from the exhaust.

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Mr. V. PENDRED asked if the glands were put through from the inside, and drawn up into their seats, and then held by being merely tightened up from the outside? If so, was there no tendency in them to work loose? That arrangement appeared to be a neat one, but it was quite new to him. He supposed the whole gland could be taken off by the turning of a lock-nut. He would like to know how often the internal stuffing-box packing required to be renewed and what it consisted of.

Mr. J. BERNAYS observed that the valves appeared to have a very large seat, and he should like to know whether the proportions shown in the drawings were correct.

Mr. BJÖRLING said that they were for low pressure.

Mr. BERNAYS said that that might be, but as there must be a very much larger pressure in a pump cylinder to overcome the resistance caused by the difference between the inner and outer diameters of the valve seats, in order to open the valve, the seat appeared to him to be too large in proportion to the centre opening. The seat seemed to be more than double the area of the opening, so that the pressure working inside the pump cylinder must be fully double the head of the column that had to be raised. Ball valves worked very well when they were well made, but he had generally seen them made in metal and carefully turned.

Mr. P. JENSEN said that it would be wrong to speak of great economy of fuel in connection with direct-acting pumps, such as the so-called "Universal." They fulfilled a want often felt, where a cheap and simple pump was required without much gear, and which required no particular looking after; and in such a case a pump like that which had been described was in its right place, but he thought that direct-acting pumps were not made in any large size. He believed they were only made up to something like 12 inches.

Mr. BJÖRLING said they were made up to 15 inches. They had a short stroke and a low lift.

Mr. JENSEN said that if a very economical pump was wanted, and especially one of large size, there would be no difficulty in applying the compound-cylinder principle, such as Mr. Björling mentioned. From what he had seen and heard of those pumping engines, they answered remarkably well. He had heard of cases in which they had been covered with water, as in the case of flooded mines, and had yet worked a very long time without any looking after. He should like to know up to what pressure the indiarubber ball valves were used with advantage, and whether the disc valves shown in the diagrams had been tried for very high pressures. He also wished to know whether the

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pumping engine (Fig. 16) had been used for compound cylinders. There certainly seemed to be a great deal of gear about it, but the motion appeared to be correct, and there was no reason why it should not work very steadily. The cataract was a well-known appliance for such purposes for shutting off exactly at the right moment, and thus preventing all accidents and breakages; and the way in which it was applied in the diagrams seemed to be very ingenious. He should think that this construction admitted, as well as the other simpler forms, of the cylinder being placed some distance from the pump if required. Such an arrangement might be useful in some cases. He had himself put one of those pumping engines to a very severe test. He tried it first by working it at the rate of about four or five strokes per minute; then he brought it to a dead stop; then he suddenly opened it full; and with a head of water amounting, as near as he could remember, to 45 lbs. pressure, which would be about 100 feet head of water, it went at its quickest speed, which was about 115 double strokes per minute, without any material shocks or vibrations. He afterwards tried it at various speeds, varying from 10 to 110 strokes per minute, and the delivery of water was very full. The pump worked as steadily as could be wished. The fact of there not being any dead points was most important as compared with some other direct-acting pumping engines.

Mr. H. Davey said he observed that the ball-suction valves of the short-stroke special pump were arranged at a higher level than the inlet to the pump. Pump-makers usually strove to keep the valves below the inlet openings, because when they were placed above they usually produced a very great deal of slip. Had any tests been made, and could the author give any data as to the percentage of slip which occurred in the present case? The arrangement of the delivery valves was subject to the same objection. The water, after leaving the valves, went directly down. If the valve was below the outlet, so that the water had to rise through the valve opening, and then above the top of the valve before it changed its direction, the change of motion of the pump caused the valve to come to its seat very readily. On the other hand, if the water changed its direction below the valve, the valve had a tendency to float on the stream, and the return stream, setting back very suddenly, would often prevent the valve getting down to its seat. The arrangement of the stuffing boxes appeared peculiar. With regard to the double-ram pump, first with the internal stuffing boxes and next with the external stuffing boxes, the internal

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stuffing box appeared to him to be open to considerable objection, inasmuch as it was necessary in a pump of very considerable size that a very large casting must be removed before they could get back to the stuffing boxes. He should like to know whether the author had ever tried any automatic means of getting the packing up, such as a spring arrangement, or some arrangement which might be actuated from the outside without the casting being taken off. He saw a plunger pump working in the north of England some time ago in a vertical position with an internal stuffing box very similar to that shown on the drawing, but it happened to be a single-acting pump, and therefore the pressure of water came only on the top of the stuffing box. He was informed that the packing in that pump never required any screwing up, as the pressure of water on the gland and the top of the packing kept it perfectly tight until the packing required renewal. There was a door provided at the side of the pump for getting at the packing. The arrangement shown in Fig. 15 was, as the author observed, one that was very much used for high-pressure pumps, and one which he (Mr. Davey) took to himself the credit for introducing into England. He believed that he was the first person who ever used such pumps in that particular form, though since their introduction a great many makers had adopted the same plan.

In the early part of the paper the author gave a rough classification of direct-acting engines, and under the head of automatic expansion he classed Haswell's direct-acting engine. The last speaker seemed to be under the same impression with reference to cataracts as the author, namely, that a cataract, as it was formerly used for pumping engines, was intended for the purpose of preventing the engine from making false strokes, or that it was a safety appliance on the engine. He (Mr. Davey) believed that he was correct in saying that, until he combined the motion of the cataract with the motion of the engine to produce the result of checking the engine, a cataract had never been used as a safety appliance. Cataracts had been used from the earliest times of pumping engines, but they had always been used as time appliances, and not as safety appliances. They merely regulated the time of the opening or closing of the valve, but they did not regulate the period of the stroke at which the valve should be opened or closed. He believed that the latter was never done until it was accomplished by his gear. The Haswell engine was nothing more than a special or a Cameron steam-pump, with the steam piston which actuated

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the valve outside the cylinder. It was just the same as though the steam piston which actuated the valve, in the external valve arrangement of the special pump, was combined with the valve itself; the valve was made as a plain ordinary D slide valve, and the valve spindle was brought through the valve chest, and a little steam cylinder and piston was provided to reverse the valve. But Haswell found that there was a very serious concussion in the opening and closing of the valve, unless some special means were used to prevent it. The concussion was prevented in the Cameron pump, and in the special pump, by cushioning with the steam in front of the valve piston. The valve was driven over the ports by steam pressure, and steam was bottled up in front of the valve piston to prevent serious striking or concussion on the covers. Haswell simply prevented that concussion by the use of a cataract instead of a steam cushion. He made precisely the same use of the cataract which Cornish engineers made years before. That was to say, he simply used it for preventing the sudden opening or closing of the valve. By the regulation of the plug in the cataract, the steam acting on the subsiding cylinder was made to open or close the valve slowly. There was no connection between the motion of the engine and the motion of the cataract. They were entirely distinct, and always had been so. In the Cornish engine nothing could be more distinct than the cataract motion. The engine simply raised a weight at the end of the stroke, and that weight being released, fell, but it was controlled in its falling by a cataract, so that at the time the cataract was acting it had no connection whatever with the engine, nor had it any connection with any of the engine movements.

Mr. A. WILLIAMS said he should like to know the relative duties of the various pumps, the mechanism of which had been placed before them.

Mr. BARKER asked what provision was made for starting the pump in case of the valves sticking, which they might do in consequence of corrosion or from some other cause.

Mr. P. R. BJÖRLING, in replying upon the discussion, said, with regard to the questions asked by Mr. Davey, that there were many ways in which motions could be got, and he (Mr. Björling) had shown the plan which Messrs. Cope and Maxwell had adopted in the present instance. Haswell's idea was not that the cataract did anything else than regulate the motion of the main valve; but Haswell made a step in the right direction, because, through adopting the plan he did, he gave other people the idea of a differential motion. The engine which he

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had mentioned as having been replaced by one of the direct-acting pumping engines (shown in Figs. 10, 11, 12, and 13) was an old beam-engine. An engine placed at the bottom of a pit without spears must be more economical. In reply to Mr. Pendred's inquiry about the glands (shown in Figs. 1 and 2), they had been working satisfactorily for some years; but those shown in Fig. 10 were objectionable, on account of the joint of the bonnet, which had to be broken to tighten it. Those glands were generally packed with hemp and tallow. Mr. Jensen had asked what pressure the ball valves would stand. It was, as stated in the paper, a head of 200 feet, or, say, 100 lbs. He could not say exactly what pressure the disc valves would stand. He believed it was about 80 yards. Those valves were made very hard and very thick. Mr. Davey had raised an objection to the arrangement of the suction and the delivering valves. He (Mr. Björling) had never liked that arrangement of valves, but they were so arranged for cheapness. All the valves were on one plane, and they were all planed together, and the place for the seats was bored out. He did not think they would give much slip. He had never ascertained the actual quantity delivered by them; but, as far as he could see, when they were working, they seemed to deliver the pipe quite full, and he had never heard any complaint of much slip.

As to the relative duties of those pumps, some of them did not give more than 25 or 20 per cent. in friction, and some gave even a great deal less. But those which had come under his notice had been worked under very trying circumstances. For instance, those which were mentioned as having 21-inch cylinders had 25 suction pipes, each 500 feet long. The difficulty of starting the "Universal" short-stroke engine was certainly an objection; but if the cylinder had been standing a long time, the slightest tap with the hammer on the top of the cylinder would be sufficient to start it.

The PRESIDENT, in closing the discussion, observed that with regard to the arrangement of the details to which Mr. Davey had objected, Mr. Björling had very fairly remarked that there were many modes of arranging the details of engines. It was scarcely to be expected that in two engines of a different type the same mode of performing the same operation would be adopted, or the same arrangements of details employed. Something had been said about the noise of the self-acting pump. Perhaps those who took exception to noise in connection with machinery were a little too fastidious. He did not think they could get what might be called silent machines. Noise was,

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perhaps, a good indication that work was being done. The details of the paper had been rather difficult to follow, and he confessed that he had not been quite able to understand the *modus operandi* of the pumps.

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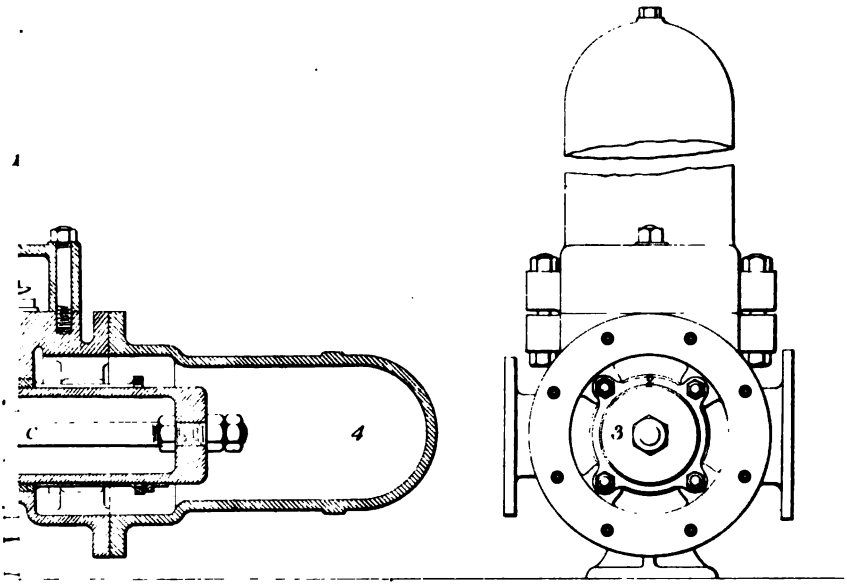
Fig. 14.



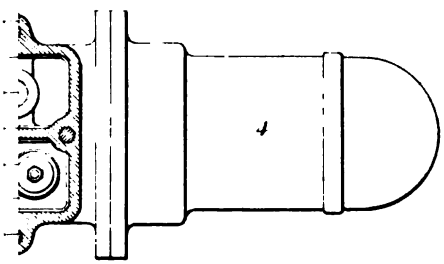


Fig. 13.

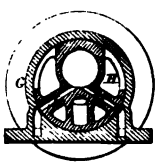


Fig. 12.

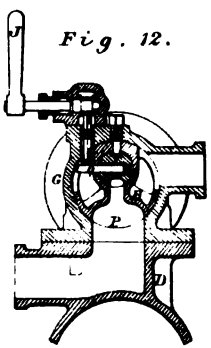


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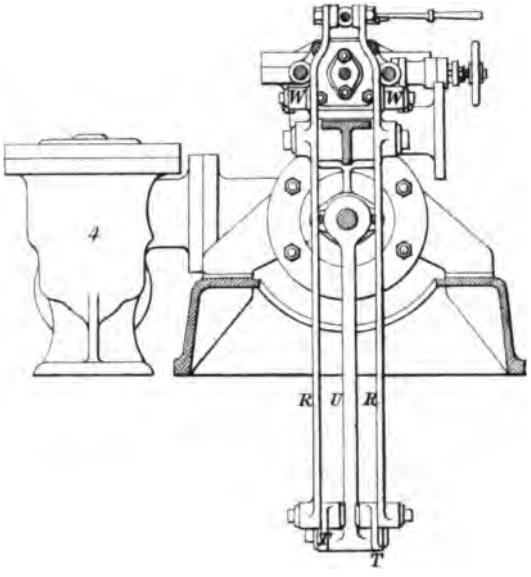
Fig. 17.



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June 4th, 1877.

THOMAS CARGILL, PRESIDENT, IN THE CHAIR.

DIRECT-ACTING HYDRAULIC MACHINERY.

By RALPH H. TWEDDELL.

Before proceeding to describe some of the practical applications of direct-acting hydraulic machinery, the author proposes to consider, firstly, the present method of transmitting power from the prime mover to the machines or tools to be driven, and afterwards to working them. He will confine his attention to such form of gearing as is understood, when shafting with straps or toothed wheels is used, and, after alluding to what he considers the disadvantages of this system, he will describe the application of hydraulic pressure to the transmission of power, and also to the working of the machine tools themselves, stating his reason for considering this system in many instances preferable to the former. There are three conditions under which intermediate gearing is necessary: (1) when the tool to be driven is some distance from the prime mover; (2) when it is desired to transform the effects of great power moving through a small space, to an equivalent result obtained by means of small powers moving through a great distance in equal times; (3) the converse of the last condition. In order to show the advantages to be obtained, in his opinon, by direct action, he will consider the case of a boiler, ship, or girder yard. It may not be amiss to remark here, that, because the author considers the ordinary mode of transmission by gearing unsuitable for the machines and cases about to be mentioned, he therefore considers it unsuitable for other machine tools; quite the contrary, the reputation of hydraulic machine tools runs more risk from too zealous advocacy now than it ever did from prejudice, when some twelve years ago he introduced his fixed hydraulic riveter.

In all the examples to be given by the author, the machines have a reciprocating action, and in proportion as they possess this feature, as the nature of their demand for power becomes more intermittent, and their distance from the prime mover increases, the more to advantage will the hydraulic system show.

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Since the comparative efficiency of hydraulic pressure, as compared with gearing, when applied to the transmission and application of power increases, first, as the distance; secondly, as the intermittent nature of the demand; and, thirdly, as the uniformity in amount of resistance of the work to be done, the folly of using hydraulic pressure for driving a shop full of lathes running constantly is evident; it is equally unsuitable to work a planing machine doing work which often varies in amount throughout every cut, and sometimes is only doing work during a mere fraction of its stroke—for example, when planing chipping pieces on a large bed-plate.

As an example of hydraulic transmission, let us consider the case of the machine shop at the Government Dockyard, Toulon, containing machinery for shearing, punching, bending, and riveting ship and boiler-work. This shop is 380 feet long by 170 feet wide, and the machines are placed to suit the requirements of the work. The engine-house also is some 170 feet from the nearest corner of the shop itself; without reckoning counter-shafts, this shop would require on the ordinary system some 1400 feet of main line shafting running at, say, 100 revolutions per minute, and in addition to this would be all the counter-shafting, belts, plummer blocks, and pulleys, in order to get up a speed of, say, 400 to 500 revolutions on the first motion shaft on the machine tools. After taking all this trouble to get up a high velocity at the driving pulley on the machine, a mass of gearing is again required to reduce it to the speed of the main shaft of the tool.

The author will now consider the disadvantages of the geared method of transmitting the power from the prime mover to the points of application, taking as an example the arrangement just quoted. In the first place, unless a troublesome and expensive system of disconnecting clutches be adopted—and if adopted, in practice they will be rarely used—the whole of the shafting, with all the counter-shafts, &c., must be driven in order to punch a small hole, say $\frac{5}{8}$ inch diameter, at the far end of the shop, not only this machine, but all the gearing in every punching and shearing machine in the shop, must also be driven. But it may be said that the workman could shift the belt when he had done with the machine; as a rule, however, he does not do so; he leaves the whole apparatus running, and sometimes even neglects to take out the stop motion. His argument for doing so is a good one, viz. that if he stops the machine, the fly-wheel as soon as it has expended its accumulated energy in doing nothing, requires more energy put into it before it will be able to punch a plate or do anything else, and

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he will not wait for that. Consequently we have shafting imparting energy and work to fly-wheels which have no capability of storing any quantity of it, and the engine consuming steam to nearly the same extent as if useful work was being done at the machines.

To put the loss represented by this into figures is extremely difficult, and the author has no intention of doing it; but it is open to him in support of his case to point out some of the contingent disadvantages incurred by using gearing, in addition to its defects as an economical and convenient arrangement for transmitting power. The cost of the shop itself is greatly increased by reason of the columns and walls having to be made of sufficient strength to carry the shafting; the shafting also continually interferes with the use of travelling cranes, and the driving belts in many cases interfere with the efficient working of any crane on the machine itself. Shafting when up requires constant care and lubrication, and the wear and tear of belting is great. There is also the question of safety; more loss of life and accidents are caused from pulling belts off and on than in any other way; and the noise, dirt, and discomfort due to this mode of transmission need not be dwelt upon. In the erection of works, everything should be so arranged as to be readily removable. Trade changes so constantly, that what may be a favourable site for a manufacture now, may be utterly unsuitable in ten or twenty years, and the buildings about a factory are of little value when all the machinery is taken out of them. So much for the transmission of power by gearing.

But it may be said it is now very common to attach a small steam-engine to such machines as have just been described, to transmit the power by means of steam carried in pipes underground, in the same manner as is advocated for water. It is unnecessary to consider the relative economical advantages of transmission by steam or by water; and supposing for the moment that the superior economy arising from elasticity of steam is not balanced by advantages due to the want of that property in water, it will not be difficult to decide in favour of water on the score of convenience and practicability, and in the long run economy. Setting aside the loss from condensation in any system of steam transmission, owing to the pressure per square inch being limited, we cannot in the majority of machines apply the pressure direct to the work. It was so used in stationary riveting machines, but the quickness and the sharp blows, which were objections even in this application, were an absolute bar to its use in that manner for punching, shearing,

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bending, or flanging, and other processes. Then again, owing to the same defect of limited pressure, it was of no use for portable machines, the heat of the steam also preventing men handling any machine so driven. Seeing, then, that after it has been transmitted steam is not capable of direct application to the work to be done, and that gearing after all is called into requisition, the result is that a punching and shearing machine, to do the same class of work as that shown in Figs. 1 and 2, requires, even with a steam engine attached to it, gearing between the engine and the tool holders. Thus, although slightly modified in degree, this system of steam transmission, while it is better than shafting, for some of the reasons already given, is as wasteful. If when placed considerably apart every machine could be kept in constant and full work, this system of steam transmission and separate engines on each machine would probably be open to fewer objections, but in practice no such case exists as a yard where every machine is worked without intermission, or which, when running, does work equal to the number of strokes per minute it is running at.

In a geared machine to do the same work as the hydraulic one shown at Figs. 1 and 2, if any of the gearing or belting breaks down, the whole machine is *hors de combat*, and everyone knows from experience how often a whole shop is laid idle until a main strap is tightened up or repaired. Indeed, very often the failure of a belt on the smallest of the machines causes a temporary slowing or stoppage of the whole shafting. But in the hydraulic system every tool holder is self-contained and independent. Since, then, the demand for power is not in practice constant, it must be intermittent, and therefore suitable for hydraulic transmission and accumulation. And since also, with steam, direct application to the work cannot conveniently be carried out, while with water it can, with few counteracting disadvantages, it is clear that direct-acting hydraulic machinery is worthy of attention. Some of the disadvantages of gearing for the purposes of transmission having been pointed out, the advantages to be obtained by using water for this purpose will next be considered; and, in addition, its peculiar applicability after it has reached the machine for the direct application of the power so conveyed to the work to be done. Every advantage which has accrued from the application of hydraulic pressure to dock, railway, and warehouse machinery, holds good when applied judiciously to the working of such a plant of shop tools as that described, and many other advantages in addition peculiar to this application. But while the author was, he believes, the first to

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adopt a similar complete system to working machine tools, he very soon found a point of departure; for while from 700 lbs. to 750 lbs. per square inch is undoubtedly the best pressure for cranes, capstans, and similar machines, it was soon evident that 1500 lbs. or 2000 lbs. per square inch would be required for machine tools; and while this was partly shown to be the case when the author designed the fixed riveter, it became essential when the invention of his portable riveter necessitated the size of every part being kept as small as possible, in order to keep the weight down. For many reasons he regrets that he did not adhere to 2000 lbs. per square inch, with which he started, but the difficulties at that time with the joints and packings compelled him to be content with 1500 lbs. per square inch.

Owing to the large number of machines which are now at work fitted with accumulators and pumps made for the lower pressure—1500 lbs.—any alteration would render additions to existing machines very awkward. At the same time in America, where the author had none of his earlier machines at work, 2000 lbs. per square inch is the pressure used. Before proceeding to state the reasons for advocating the system of hydraulic transmission, a short *résumé* of the progress of its application to machine tools may be interesting.

The high pressure of steam necessitated by the introduction of compound engines, made severe demands on the makers of marine boilers, and it was to overcome the difficulty then experienced in making tight riveting in plates 1 inch thick, that the author designed the stationary hydraulic riveter shown at Fig. 3. Messrs. Thompson, Boyd, and Co., of Newcastle-on-Tyne, were among the first to manufacture compound engines, and they not only at once appreciated the advantage such a machine would give them, but arranged to make and try one, and for several years worked it to great profit to themselves and advantage to their boiler work. But a machine which closed $1\frac{1}{4}$-inch and $1\frac{3}{8}$-inch rivets at 4*s*. per hundred well instead of from 26*s*. to 36*s*. per hundred by hand badly, was not destined to be long a monopoly, and arrangements were therefore made with that firm for its manufacture and introduction to the trade.

The differential accumulators seen at A, Fig. 3, consist of a vertical pillar of a larger diameter at the bottom than at the top; a cylinder packed at top and bottom, on which are also placed the weight-rings, slides up and down this spindle; the pressure of the water acting on the annular surface is sufficient to raise the cylinder and rings. The weight of these acting on the water imparts to it a pressure of 1500 lbs. per square inch.

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This accumulator having only a very small area, will fall a considerable distance when any demand is made upon it; thus, while the ram carrying the die of the riveter travels 2½ inches, the cylinder and rings, weighing some five tons, will fall 24 inches. The result of this arrangement is that owing to the shock caused by the suddenly arrested fall of the weights, the effect of a sharp blow is obtained on the ram of the riveter, as well as the steady pressure, characteristic of hydraulic power; there are many cases where this property is very useful, and to this combined feature is due the success of hydraulic riveting, especially for boilers.

The application of hydraulic pressure to riveting and chain cable shearing having proved so successful, the attention of the author was directed to designing a portable riveter. All previous machines proposed used steam, but for reasons already stated this was not successful, and amongst many others the disadvantages arising from the heat of the steam were very great. Although the portable hydraulic riveter shown at A and B, Fig. 4, is not able to do some of the work which, owing to the percussive action obtainable by steam, one constructed on the latter principle would do, but for the defects inherent to steam, the one illustrated, by its portability, enables a large amount of work to be done on such parts of girders, ships, and boilers as from their weight cannot be moved so cheaply to the machine as the machine can be to them, and also a great deal of work which a steam or air machine, even if portable, cannot do This machine, weighing only 5 cwt., and exerting a pressure of 35 tons, is a favourable example of the transmission and concentrated application of power, at the same time ensuring direct action and total absence of gearing. Another form of portable hydraulic riveter for fire-hole rings, lattice girders, &c., is shown in end and side views at Figs. 5 and 6, and forms a very compact arrangement for that purpose.

As an instance of the adaptability of the hydraulic system for transmission, it may be mentioned that with a suitable arrangement of crane and connecting pipes the portable riveter can be brought to a rivet at any point within a cubic range of from 30,000 feet to 40,000 feet without disconnecting a joint. These machines are now used to rivet up locomotive fire-boxes, locomotive fire-hole door rings, smoke box ends, and engine and tender frames. Every rivet can now be put into a Cornish Lancashire boiler by these and the fixed machines, including putting on the domes. Latterly the subject of riveting bridges by machinery has occupied much attention. There are many parts of bridges, even when intended for export, which can

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be sent away in pieces much too large to allow of their being handled over a fixed riveter, thus affording employment for a portable machine, but there remains even then a considerable amount of riveting to be done on the bridge when erected on its site. Mr. Edward Wilson, C.E., afforded the author the first opportunity of riveting a bridge *in situ* by hydraulic pressure at Primrose Street, in connection with the Liverpool Street Station of the Great Eastern Railway.

Figs. 7 and 8 show a general arrangement of a self-contained travelling plant for this purpose, as manufactured by Messrs. Fielding and Platt, of Gloucester. It may here be interesting to point out that great speed of working is quite consistent with the use of hydraulic power; a speed of twenty rivets per minute can be obtained, and 5000 rivets in nine and a half hours; or a steady average of eight per minute is the day's work when riveting straightforward work, and from 1800 to 2000 rivets in very irregular lattice girder work is the regular day's work for one machine, at a saving of something like 50 or 60 per cent. on cost per 100 over hand, 250 to 300 being a very good day's work for one set of riveters.

In the year 1872 Mr. E. J. Welch adopted the author's system for working punching, shearing, and corrugating machines; and in 1875, when the same gentleman commenced the large works of the Stephenson Boiler and Forge Company, at Failsworth, near Manchester, he laid out the whole with a complete system of hydraulic mains, separate engine and accumulator house. In addition to working the hydraulic riveters, &c., he applied hydraulic pressure to cranes and lifts all over the works, effecting a very great economy in the items of labour alone.

In the year 1875 the French Ministry of Marine, through Mr. Henry Chapman, of Paris, proposed to adopt the author's hydraulic system in their new shops at Toulon. This work involved other difficulties than those connected with the hydraulic system: to commence with, M. Marc Berrier Fontaine, Ingénieur de la Marine, Toulon, insisted on every punching and shearing machine having 5 feet gap, and this, for a machine to punch 1¼-inch holes in 1¼-inch plates meant castings of great strength. Some of these machines weigh 26 to 28 tons, the pumping engines are each 50 H.P. actual; there are two accumulators 14 inch each in diameter and 20 feet stroke, each loaded to 1500 lbs. per square inch, and a number of punching and shearing machines, varying from a power equal to punching 1¼ inch by 1¼ inch, and shearing 1¼-inch plate to working ⅝-inch plate. There are also quadruple machines

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capable of shearing and punching steel angles 6½ inch by 6½ inch by ½ inch, and other hydraulic bending machines for H and L iron, a complete set of riveting plant for marine boilers, with differential accumulator, and also portable riveters for riveting the cellular bottoms of ironclads. The hydraulic pressure mains are 2½ inch diameter, the return pipes are 3 inch diameter, and are laid alongside each other in trenches round the shop beneath the floor.

The Hydraulic Engineering Company, of Chester, manufactured from the author's designs the engines, accumulators, pressure and exhaust mains, and the powerful punching, shearing, and bending machinery. The authorities at Toulon are now connecting to the existing main hydraulic capstans, cranes, forging and moulding presses, and also special bending machines for the garboard plates of ships. The advantages arising from the use of the author's hydraulic system of transmission may now be briefly pointed out. In reference to transmission, the accumulator being pumped up, the mains once filled, the engines are automatically stopped. Should it be necessary to punch a ⅝-inch hole by a machine at the far end of the shop, no intermediate transmitting gear is disturbed, or any of the other machines; the man has not to wait until he pulls the belt on to the fast pulley or starts the donkey engine, waiting until the condensed steam gets away from the cylinder and pipes, but he pulls the valve handle and the hole is punched, the accumulator falls in exact proportion—in this case about ½ inch, in so doing it opens the throttle valve, and the engine moves round, in this case, about one quarter of a revolution, and again all is at rest. Supposing, on the contrary, a man wants to punch twenty holes per minute, as soon as the accumulator falls the engine starts and works in proportion to the demand: the accumulator also ensures a uniform pressure, while at all other times it regulates the revolutions of the engine in exact proportion to the work actually being done. Supposing a man carelessly put in a 1¼-inch plate under the punch of a machine for ⅝-inch plates only, there is no danger of fracture, as is the case from the arrested momentum of a fly-wheel; the pressure can never exceed that due to the pressure on the ram from the accumulator; the accuracy and absence of risk from blind holes is obviated, owing to the perfect control of the movements of the ram by means of the valve handle; there is no noise, no dirt, no dust; no side walls, columns or beams are required for shafting; a light iron roof covers all, and a clear headway is left for the travellers. There is no danger to the workman, the wear and tear is in exact proportion to the work done; if no

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work is being done nothing is moving, therefore no wear and tear. Not only is there a collateral saving in the shape of buildings above the ground, but underground foundations are not required for the machines.

There is no getting up speed only to reduce it again, as in the geared machines, and the loss due to friction in the pipes is very small, as was proved by experiment, besides being a constant amount; whereas in shafting the friction increases as the accuracy of the shafting decreases, owing to wear and tear; in fact, when the pipes are once laid in their trench, they require no looking after and cannot go wrong. Finally, nothing is left to the workman; he finds the machine ready when he wants it, and it wants no care when he leaves it. Thus, in addition to its advantages for transmission, hydraulic pressure is equally convenient for obtaining direct action in machines to be driven.

The author trusts that, after this explanation, it will not be considered that he has wasted the time of the meeting in drawing attention to an application of hydraulic machinery, which has occupied a large portion of his time and attention for some years.

DISCUSSION.

Mr. W. H. Le Feuvre said he believed the author of the paper had in several instances used hydraulic apparatus in swing bridges. He should like to know whether the author could state what economy might be effected in such bridges by using hydraulic machinery.

Mr. F. E. Duckham said there was no doubt a great advantage in using hydraulic machinery for many purposes, and more especially for those to which Mr. Tweddell had referred. Mr. Tweddell had shown very clearly that if machinery was working with shafting in a shop, that shafting was continually going whether one or more machines were being used, and even whether any work was being done or not, and there was considerable loss in friction and repairs. With hydraulic machinery pipes would be laid down out of sight, and those pipes would not get out of order from wear and tear or friction. If there was any particular work to be done, the machine which actually did the work was the only thing which moved, except the pumping engine, which moved in precise proportion to that work; thus no more power was used than was required. The same principle was applied in many of the docks for working cranes, bridges, and lock gates. He believed that the system was the best which could be used for such purposes, and that

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there was nothing which would exceed hydraulic power in efficiency in the case of machines which required to be under the immediate and perfect control of the attendant.

Mr. E. J. C. WELCH said he had laid out the works with which he was connected (those of the Stephenson Boiler Making and Forge Company) entirely upon the hydraulic system, as far as it was applicable to the purpose. He had, in the first place, built a separate building in which the engines and pumps and accumulators were fixed. The engines were automatic, inasmuch as they started and stopped themselves, and they had a variable expansion gear. The engines ran three times as fast as the pumps, and that difference of speed enabled him to avail himself of the expansion arrangement, which was thrown entirely out of gear when the engine was going very slowly as at starting. That caused a great economy in the pumping, which, of course, was the starting point of the hydraulic system. The accumulators were 8 inches diameter, and had a 14-foot lift. There was a tumbling gear attached to them which threw the pumps in and out of action, and the accumulators had a play of about 10 feet between stopping and starting the pumps. The hydraulic mains were laid throughout the whole of the shops. In the boiler shop, which was about 230 feet long by 100 feet span, the hydraulic main was laid along the centre of the shop, with a hydrant at every 15 feet for the purpose of attaching the portable riveters and punching machines. Those were connected with the hydrants by a small copper tube of about three-sixteenths bore. Special portable fires were fitted up to supply the rivets, as the work was done so quickly that the ordinary fires could not give an adequate supply of rivets. The fires were all connected by indiarubber tubes to air mains laid throughout the works and supplied with air by one of Baker's patent blowers. One of the fixed riveters gave a pressure of about 35 tons on the rivet, and the work which it did was very superior to that done by any other form of machine. The rows of rivets connecting the flues with the boiler ends had to be put in by hand, but the end plates were put on to the shell by hydraulic power. The pressure used was 1500 lbs. on the inch, but the pressure might have to be raised to 2000 lbs. to work with thicker plates. In the fixed riveters hemp packing was used, and it was much better than the leather, because, if the hemp packing wore a little loose and began to leak, a very slight amount of screwing up would stop the leak at once, and there was no occasion to stop the machine. A number of cranes were also working off the same mains.

Mr. J. N. PAXMAN asked Mr. Welch whether he was driving

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the general plant by hydraulic machinery. The meeting had not had laid before them the prime cost of hydraulic punching machines, and the cost of steam machinery for doing the same work. He asked the author for information upon that point, and also whether he had any difficulty in frosty weather. He (Mr. Paxman) thought that the application of hydraulic machinery, especially to bridge building and boiler making, was excellent.

Mr. E. J. C. WELCH, in reply to Mr. Paxman, said that the hydraulic machinery of which he had been speaking was more particularly a boiler and girder plant. The machines were not rotary, but reciprocating. The same water was used over and over again in the pumps and machinery. In winter a gallon of glycerine was put into about 300 gallons of water, and no trouble whatever arose through the freezing of the water, though the works were in an excessively exposed position.

Mr. A. RIGG said that engineers were indebted to Sir William Armstrong for the present wide application of hydraulic machinery, but great credit was due to Mr. Tweddell for his success in compelling people to adopt it for various purposes, when their prejudices were strongly opposed to doing so. He (Mr. Rigg) had made the largest hydraulic riveting machine in this country, upon Messrs McKay and Macgeorge's patent, and there were two or three points in which he very considerably differed from Mr. Tweddell's arrangement. Taking Fig. 3 as an example, the objection which he had to that was that the hydraulic cylinder was rather in the way if they wanted to do such work as the internal tube plate of a locomotive without some inconvenient makeshift, and it could only be done with a comparatively light portable machine. His own arrangement was exactly similar to that of Mr. Tweddell's portable machine, only it was turned the other way up. The cylinder went down into a recess in the ground, and therefore kept all clear. There was nothing standing up but a wrought-iron girder and a cast-iron girder, and those closed together upon a hinge. With regard to hemp packing, it was in all circumstances better than leather, for leather soon gave way under constant work and gave considerable trouble. He had used hemp packing for pressures ranging up to 1000 lbs., and attributed some of the difficulties which Mr. Tweddell had to deal with, in connection with cup leathers, to the blow which was given by the falling accumulator. His (Mr. Rigg's) experience led him to conclude that the falling accumulator was not a very good arrangement. It gave a heavy and transient blow, whereas what was wanted was a steady pressure. He had got

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over a difficulty in removing the loss of power caused by Mr. Tweddell's plan by the simple expedient of having a smaller cylinder. When the pressure came on to the small cylinder it gave a comparatively small power while they were working its ram forwards, but when the dies were together the larger cylinder came into operation, and then there was a greater power when doing the actual work which the machine was intended to perform. The large machine appeared to him to be an excellent application of the hydraulic system to shearing and punching, where, of course, considerably more power was required than was necessary for riveting. The form of the casting did not seem to be the best for strength, but he supposed there was a bracket beneath the ground. In a place like a wharf or a railway yard, there was nothing better than the hydraulic system for working capstans and cranes. As members of the Society of Engineers, they had nothing to do with the question of cost. The question with which they had to deal was that of economy in results.

Mr. M. BROMLEY said that at the Stratford shops of the Great Eastern Railway they had had one of Mr. Tweddell's riveters in use for eighteen months, and they even put on the front tube-plate by means of it, which one of the speakers did not think possible. He had inquired how many failures had occurred with rivets put in by the hydraulic machine, and the most that the workmen would admit was that one rivet had leaked in one boiler. With regard to the economy of using the machines, he had found that with one riveter, one labourer, and one boy, 300 boiler rivets could be put in in one day, while for doing the same work by hand they would require twelve men and four boys. The hand work required to put in these 300 rivets would cost 3*l.* 6*s.*, and the work when done by Mr. Tweddell's machine would cost only 11*s.* So satisfied was Mr. Adams with the result of the hydraulic machinery, that he had determined to have machines for the fire-hole and foundation rings. He (Mr. Bromley) had estimated that the cost of putting in one fire-hole ring by hand was 12*s.* 6*d.*, while with Mr. Tweddell's machine the same work would cost only 3*s.* The cost of putting in the foundation rings by hand-labour was 1*l.* 17*s.* 7*d.*, and the work occupied two days and a quarter. By means of Mr. Tweddell's machines they would be put in for 9*s.*, and he had found that the total cost of Mr. Tweddell's plant for locomotive boilers, including that which they had in use and that which they had to order, would be 795*l.* That would turn out fifty-six locomotive boilers in a year, with 950 rivets in each. Allowing interest at 6 per cent., the saving in labour

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alone would be 470*l.* a year. That estimate put entirely out of consideration the question of time.

He did not think due weight had been given to the question of repairs. Well-designed and well-made hydraulic machinery gave very little wear and tear. He had often been asked with regard to the hydraulic riveter, "What is the use of going all the way round to do the work with hydraulic pressure when the measure of the work done was simply the strap that drove the pumps?" The answer was that hydraulic machinery was very much cheaper because it required no repair, and it always stopped and started when it was wanted. In steam riveting there was a sudden violent blow which shook everything, but in the case of hydraulic pressure there was a steady squeeze. In riveting copper he reduced the pressure to 25 tons, but in riveting iron he always used 30 tons.

Mr. W. SCHÖNHEYDER said he thought that a great deal of the success of Mr. Tweddell's hydraulic machinery was due to his not attempting to push it too far. He was very much struck about a year ago to see a large amount of riveting being done by hand in a boiler shop in the north, where machinery might have been used with advantage. The rivets received a few slight blows from a light hammer, and they were finished off by small hammers, which the men continued to use after the rivets were almost cold. That made a very unsatisfactory job; but the hydraulic riveter would be an advantage to the boiler-maker. Since the introduction of the hydraulic riveter, modifications had been made in boiler construction in order to enable the rivets to be put in by that machine. It would be useful if Mr. Tweddell would state what those modifications were.

Mr. H. CHAPMAN said that the pressure named, when speaking of different classes of Mr. Tweddell's machines, was only that on the ram at starting; viz. that due to the static load of the accumulator. The pressure actually transmitted to the riveting tool at the end of its stroke was much greater, being increased by the effect of the suddenly arrested momentum of some tons of metal weights, falling through a much greater distance than that travelled by the riveting ram. That additional power came into action at the right moment also; namely, when the rivet was getting cooler, and therefore required more pressure to close it, and that terminal force served to give the plates a good nip before the contraction of the rivet came into play. Those results were due to the differential accumulator, adopted by the author; an arrangement which enabled him to dispense with bulky weight cases and large cylinders.

Mr. V. PENDRED asked the author whether any accidents

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had occurred through the bursting of cylinders, and whether in such a case the pieces of cast iron simply fell down or had any tendency to fly. In some cases air had got into the water when hydraulic pressure was being used, as in the testing of boilers, and accidents had occurred from the pieces of iron flying about. Another question was whether Mr. Tweddell had ever applied his apparatus to cold riveting. In the United States boilers for working very high pressures used to be cold riveted. The plates were thin, and it was found that far better results were obtained from cold than from hot rivets. One thing was, that it was impossible to use rivets made of bad iron in cold riveting, for it could not be closed up.

Mr. P. JENSEN asked the author what pipe-joints were used for 1500 lbs. hydraulic pressure, and if he had used Armstrong's ordinary gutta-percha joints for pipes which had to sustain pressure. He was glad to hear the author was so satisfied with hemp packing. He (the speaker) had used it for 700 lbs. and even for 1000 lbs. pressure, but he was not aware it could be successfully used for a pressure of 1500 lbs. He wished to know if Mr. Tweddell had used steel or any other material besides cast and wrought iron for cylinders.

Mr. H. CONRADI said that before it could be positively stated that hydraulic machinery would be more useful in engineering works than steam machinery, a fair comparison between both, applied under equal conditions, ought to be made. Hydraulic machinery would only be useful where there was plenty of water. It must further be remembered that, in order to bring the water from any distance to the machines, pipes, hydrants, and other similar appliances had to be used. That, however, would not perhaps be more expensive than the ordinary shafting necessary in connection with steam machinery. Assuming hydraulic machinery to be fixed, great difficulty would arise in using it in the winter in very cold countries, and also in the summer in hot climates. It appeared therefore that hydraulic machinery could not be used so generally as steam machinery. With regard to repairs he thought the former would cost more for that through breakages.

Mr. W. PETRIE said it would be interesting to know whether any special arrangement was required to meet the expansion and contraction by changes of temperature, in the case of great lengths of pipe with such powerful hydraulic pressure.

Mr. F. W. HARTLEY said no doubt water power could be applied for punching and riveting better than steam power. As he understood the matter, the power of the engine was exercised simply in lifting the accumulator, and the accumu-

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lator was ready to serve its purpose when it was called upon; but the fire under the boiler and the pressure in it had to be maintained during the time when the accumulator was not acting. He should like to know the relative saving that might be effected by the neglect of a fire for a certain time when the accumulator was not in operation, as compared with the maintenance of a boiler under high pressure when steam was applied direct for punching and similar operations.

Mr. A. G. R. HARRIS said that the last speaker had drawn attention to the fact that there must be a loss of power in keeping the boiler at full pressure. But he (Mr. Harris) did not see the difference in the case of the accumulator not being at work, except that it was possible then to reduce the fuel supply to the consumption of power in the engine; whereas if they used shafting and machinery they must go on driving the shafting and machinery whether they were using any of the machines or not. Therefore it was quite clear that in that point alone the saving must be very greatly in favour of hydraulic machinery. When water was not being drawn from the accumulator, it automatically cut off, by means of a throttle-valve, the supply of steam from the pumps. Therefore there was nothing required except the keeping up of the pressure in the boiler. There was no power so economical for operating at a distance as hydraulic power, nor power so tranquil in its operation or so easily controlled. Any deterioration or damage in the machinery was instantly perceived, whereas with shafting and other kinds of machinery deterioration was very difficult to discover.

Mr. E. J. C. WELCH observed that he had found very great advantage from the momentum of the accumulator at the end of the stroke, and that was one of the very important distinctions between the action of the accumulator and the action of the steam riveter.

Mr. J. PLATT said he had Tweddell's fixed hydraulic riveting plant with which he did all the work which could be got to the machine, and in addition to that he had a portable riveter, which was extremely useful for various kinds of work which could not be taken to the fixed machine. His riveting plant was used for boiler-making, bridge-building, and boat-building. The rams in his hydraulic machines were packed with hemp, and that packing lasted during twelve months' constant working. He had got over the bursting of cylinders by making them of greater strength. He had some instances of bursting when he first used hydraulic machinery, but those were due to the cylinders being made extremely light to keep down the

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weight of the portable riveter; since he had put sufficient metal in the cylinders he had had no trouble from that cause.

Mr. R. H. TWEDDELL, in replying upon the discussion, said that his great object in designing his hydraulic system of machinery was to obtain simplicity. He had, therefore, dismissed all ultra-refinements respecting economy in the quantity of water used when by so doing he could avoid complications and the consequent necessity of frequent repairs, and could ensure that it should be ready when wanted. As some details had been asked for, he would mention that the cylinder contained a plunger acting on the same principle as Bramah's hydraulic press, but with many additions. He was satisfied that to Bramah was due the credit for the invention and introduction of hydraulic machinery, and no inconsiderable share of credit was due to Mr. Benjamin Hick, who invented the cup-leather, which for very high pressures made the press practicable. However, he (Mr. Tweddell) had found that hemp-packing answered all the purposes for which packing was required in his hydraulic machines, working at 1500 lbs. per square inch, although he did not mean to say that it would answer in a hydraulic press working occasionally up to two and three tons per square inch.

As the time was limited, he could not answer Mr. Le Feuvre's inquiry as to his experience in hydraulic swing bridges. Mr. Welch had raised the question of using expansion in the steam engine. That was a point which he (Mr. Tweddell) had always advocated in all previous practice. For docks and warehouse work the engine piston, moving at as slow speed as the pump plungers, rendered it impossible to obtain economical results in the prime mover. In reference to Mr. Paxman's inquiry as to the prices of the various machines, it was difficult to give prices off-hand, because circumstances differed in various cases.

With regard to the effect of frosty weather, he had had no trouble whatever. He had sent machinery to Russia, and had never heard of any trouble arising from the frost. In a workshop all that was needed to protect the pipes from the cold was to put them about 18 inches or 2 feet under-ground. Where the water was used over and over again, a little methylated spirit mixed with it would prevent it freezing. With regard to the machine to which Mr. Rigg had referred, he (Mr. Tweddell) was disappointed that the proportions were disapproved of by Mr. Rigg, for he had himself considered that it was rather a handsome machine. Mr. Chapman, in reply to Mr. Rigg's observations as to machines of more power, had already clearly

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pointed out that by using a differential accumulator, having a considerable fall, the final closing pressure on the rivet was much greater than the amount given as the power of machines of different classes. Mr. Schönheyder had urged the necessity of not pushing the system too far. He (Mr. Tweddell) was glad to hear that remark, for the harm done to the development of a system by one misapplication was greater than the good achieved by fifty successes. The statement which had been made with regard to modifications in the shape of boilers to facilitate the use of hydraulic machinery was hardly correct. He had never asked for any modifications in boilers, although some engineers had altered bridge-work, girders and boilers to suit the machines. At the same time no radical alteration had been made in any of the standard types of boilers.

With respect to the bursting of the cylinders, about which Mr. Pendred had inquired, he (Mr. Tweddell) had never known such an accident to happen except in the earlier portable machines, which were burst through the attempt to keep the cylinders thin to ensure lightness. Proper precautions were taken and instructions given to the workmen for expelling the air. As to cold riveting, it had been done by the machines. Some was done at Gloucester, but it was a complete failure; but he thought that that was due to the quality of the iron. With regard to the joints, he used no joints of any particular class. The only joint which he used in ordinary wrought-iron work was a right and left handed joint, with one end coned and the other end flat. The pipes used at Toulon were merely cast-iron pipes with the usual Armstrong hydraulic joints. In answer to Mr. Conradi's remarks as to the necessity of having a large supply of water to work the machine, he had already stated that the water was used over and over again, and therefore he did not think that the machines would be likely to run short of water in any part of the world. As to the expansion and contraction of the pipes, which had been referred to by Mr. Petrie, that difficulty was met by the use of an ordinary spigot joint.

The PRESIDENT, in closing the discussion, said that the efficiency of riveting by hydraulic machinery was equivalent to that of any other kind of riveting, whether performed by steam or by hand. The other point to be considered was the cost, both as regarded first cost and cost of maintenance. The first cost seemed to be pretty much the same as the cost of steam machinery. There must evidently be the same appliances for lifting and moving the boilers and girders and other ironwork to be riveted in both cases, and the cost of the accumulators

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and underground works might be set against the cost of the appliances in connection with steam machinery. Hence probably there would not be much difference in first cost. The cost of maintenance was a very serious point to be considered, and it really was the great test in the working of a machine. The cost of maintenance was a perpetually recurring item, and it was one which bore heavily upon the design and upon what he might call the principle of construction, whether it was a girder, a bridge, a roof, or any other part of engineering construction. In speaking of the efficiency of different modes of riveting, they must not impugn the old method of riveting by hand, because they must bear in mind that in girder-work sent abroad, the sections of which might be put together in this country by machinery, the joints had to be made by hand-riveting when the girders reached their destination. There were parts of the world to which ironwork was sent where it was necessary to make the joints good by hand-riveting. There was no question, however, that, taking a large quantity of riveting, machine-work was best. All machinery which saved hand labour, and brought the cost of maintenance to a minimum, was worthy of consideration and encouragement by engineers. A uniform system of working, of which the cost was known and upon which they could calculate with certainty, was one of the greatest *desiderata* in engineering.

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Fig. 2.

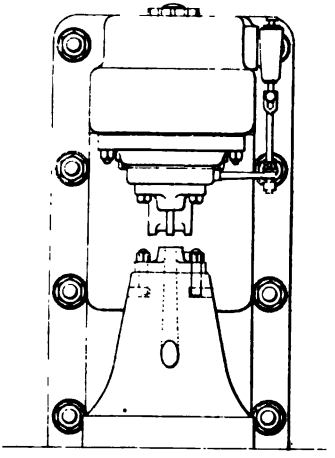

Fig. 6.

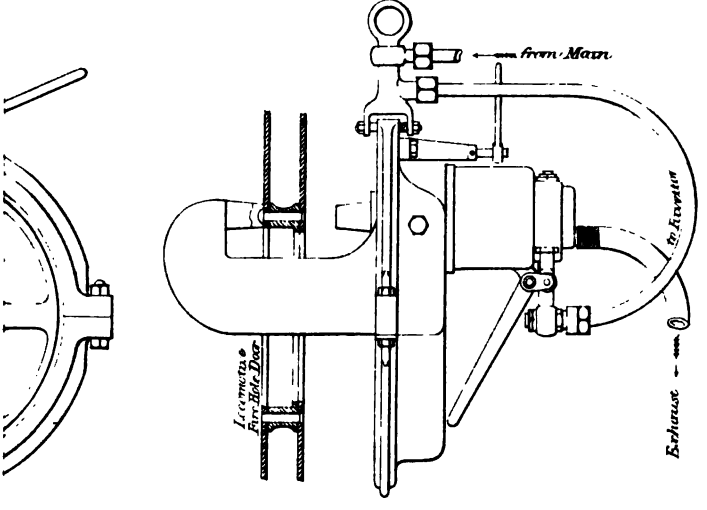

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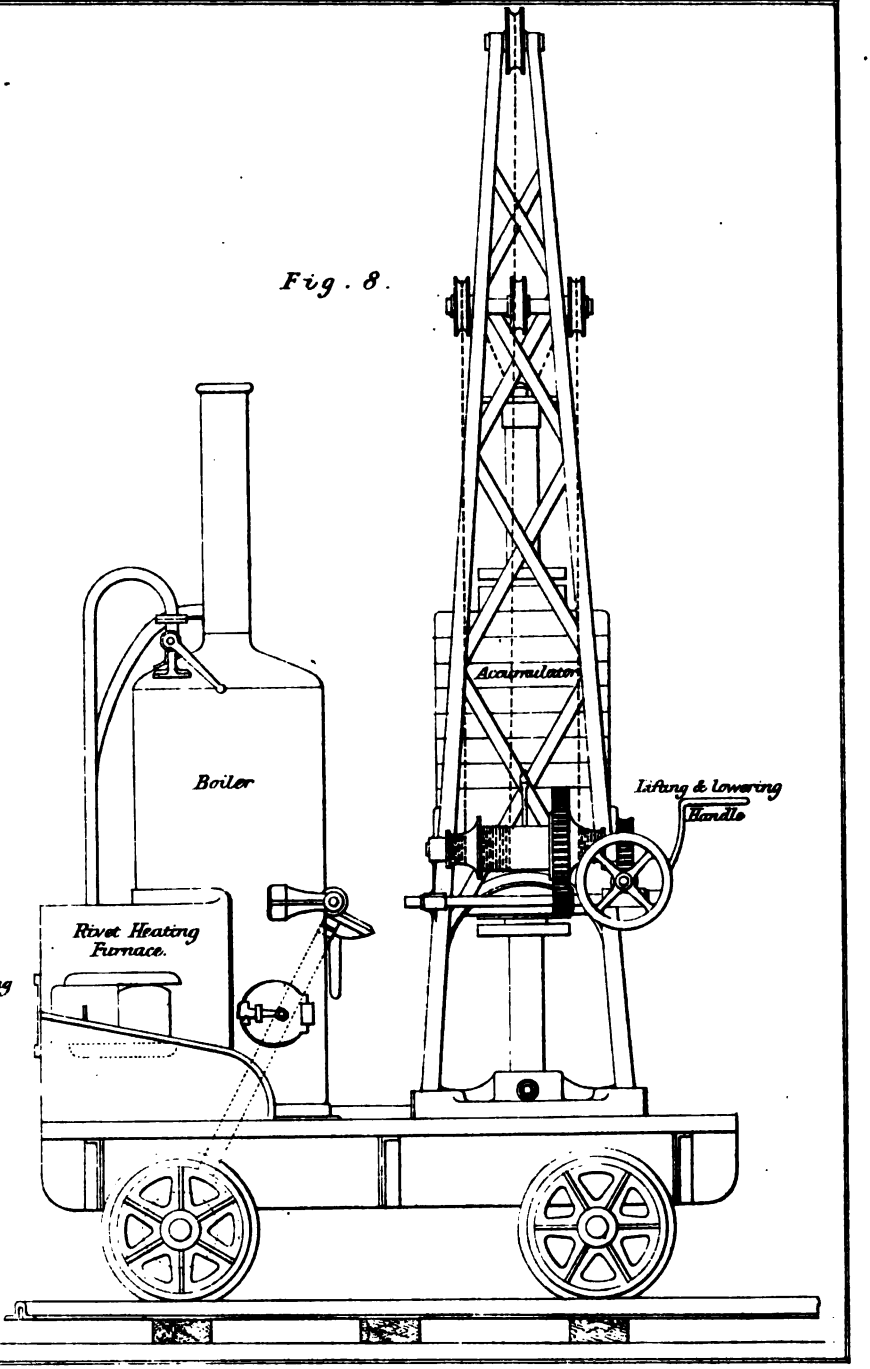
Fig. 8.



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October 1st, 1877.

THOMAS CARGILL, PRESIDENT, IN THE CHAIR.

RURAL SANITATION.

By GEORGE WM. USILL.

Sanitary science may be said to have only shown any real signs of development during the past twenty years, and it has been the work of patient but persistent advocacy, by earnest reformers, to bring the authorities to anything like a realization of the necessity for sanitary administration. The result has been so far satisfactory, considering the strong prejudices that have had to be overcome—prejudices which in many instances have been based upon a total ignorance of sanitary laws, and which have been materially assisted by the crude experience of the past, regardless of altered circumstances and the requirements of the present day.

As time has advanced, and with it the rapid progress of civilization, the sanitary condition of populous districts has forced itself upon the unwilling consideration of the authorities. In the majority of cases, it was left to the discretion of corporate and other authorities of towns to carry out sanitary works, Parliament having only very recently given its serious consideration to the necessity for prompt measures of reform. The passing of the Public Health Acts was a great step in the right direction. But whilst much has doubtless been done, there still remains a considerable task to be accomplished.

The appointment of Royal Commissions upon the Health of Towns, the Pollution of Rivers, and other sanitary matters, assisted by the voluntary but valuable researches of the British Association and other societies, have, as it were, been the means of awakening the authorities and those interested, not only to a sense of the evils of a want of sanitary administration, but of indicating the best means of effecting their remedy.

No subject has given rise to greater controversy than sanitation, the cause being that those who are responsible for the health of towns have been in total ignorance of the first laws of sanitation, and have obstinately looked upon the improvements thereby necessitated as innovation, and of a nature to call

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forth their most stubborn opposition; and it has been due to this cause alone that sanitary reformers have had such an uphill and discouraging task to perform. It has really been due in many instances to the voice of nature, appealing by the ravages of epidemics to the humanity and common sense of the custodian of the public health. And even when fever has broken out, the authorities have been loath to believe that it is due to the want of proper sanitary measures, but would rather attribute the cause to an importation of the disease.

The proceedings of the Society have from time to time been enriched by valuable contributions from some of the most eminent of its members, and the subjects treated by them, together with the discussions they have evoked, have enhanced in no small degree the important question of sanitation. Conscious of this, the author feels diffident in offering the following remarks. But whilst claiming to advocate nothing new or original, he feels that the discussion of so important a question as that under consideration will lead to a good end.

It has been argued that only cities, large towns, and populous districts require sanitation, and that villages and rural districts, by their location, are placed entirely beyond the necessity for such works. Rural districts may not perhaps have equal requirements to more populous places, yet proportionately they have as great a claim to consideration, and in many cases experience has shown it in a greater degree. It must not be forgotten that the social condition of the inhabitants of villages and hamlets is very different from that of the population of cities and towns, and this plays a very important part in the question, and one which appears to have been greatly overlooked.

In this metropolis the inhabitants are, as it were, climatized to the atmospheric influence of the surrounding district; the air we breathe in London is so adulterated that we in time really become accustomed to exist in an atmosphere which would simply poison our country brethren. Take for instance a crowded church, theatre, or other public resort. But also the open air of London is vitiated with all sorts of impurities, due to the peculiarities of the district, and the same applies equally to manufacturing towns. But in the country, the labourer, accustomed as he is to pure air the whole day, during his avocations, must of necessity be seriously affected by want of ventilation, effective drainage, and a supply of pure water. His regular habits and diet are of a nature to require this; but bad air, close rooms, and unwholesome water cannot conduce to health. It has been proved that the death rate from epidemics has been greater in proportion in rural districts than in populous

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districts, and no doubt large numbers of the inhabitants of rural districts are carried off by causes entirely attributable to defective sanitation.

But not only does the absence of sanitation materially affect the health and well-being of the inhabitants of rural districts, but directly and indirectly it influences the whole community. In the metropolis, and in all our large cities and towns, we are dependent upon rural districts for our food supplies, and thus the defective sanitation of the districts whence these supplies are derived plays a very important part in the health of the towns, and may be said even to influence their death rates. It has been proved beyond dispute, that a contaminated source of water supply, in some far distant and healthily situated village, has been the means of conveying into the heart of London the germs of disease which has destroyed many lives. The author refers particularly to the milk supply to the metropolis, upon which health so largely depends, and which by some means or other can be made the medium of spreading epidemics. It is chiefly to this point the author refers, when he says large cities and towns are directly and indirectly affected by rural sanitation. The outbreak of typhoid fever in Marylebone some few years ago, and the animated controversy thereby occasioned, will doubtless be well remembered. The advocates of sewage disposal by irrigation were taunted with having established a theory of the purification of sewage, which was now proved to be most disastrous in its results, for the cattle grazing upon the crops so produced were said to have taken up the germs of disease propagated in sewage, and the milk derived from them was thus contaminated, and, in its turn, was the vehicle of contagion to the consumers. Mr. W. Hope, in order to prove the fallacy of such an assertion, offered to place at the disposal of the authorities one of the delinquent cows, for the purpose of an analytical investigation. The author does not remember whether this offer was accepted, but the real cause of the disaster was subsequently traced, beyond doubt, to an apparently innocent circumstance, viz. that the water used in the dairy operations was taken from a polluted source; and there have been numerous similar instances.

Seeing, then, that our urban population are entirely dependent upon rural districts for their milk, the subject appears to be a grave one. The nineteenth century civilization consigns to a very great extent its infantine populations to artificial nourishment. There are others also dependent upon the nourishing qualities of milk, viz. invalids, and this renders it all the more important that the sanitary condition of villages and rural districts should be as perfect as possible.

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The food supply to the metropolis and other populous places is doubtless a very important branch of the question; but apart from this, there is the health and welfare of the inhabitants of these rural districts.

Sanitary administration in rural districts is surrounded with many and great difficulties, which will be far less easy to surmount than those in some populous places. The Public Health Act of 1872 and 1875 have certainly done much to pave the way, but it is to be feared that their operations will be confined exclusively to districts geographically favourable. Villages and hamlets in close proximity to each other may doubtless be embodied into some well-defined scheme; but it is in isolated localities that the difficulty will present itself, and this applies more to the question of drainage than to water supply.

Rural sanitation comprehends the maintenance of pure air throughout all inhabited parts of the district, by effective drainage and the removal of the foul liquid refuse of dwellings, by proper ventilation of the houses and prevention of overcrowding, and by an adequate supply of wholesome water, with other such improvements in the way of scavenging and the removal of objectional matter from the roads, and watering the same, as circumstances will allow.

It is impossible to perfect such works in ordinary villages, for the position and construction of the house will offer no small difficulty. Much, however, may be done, even with the existing state of things, and a great deal can be done with new dwellings. It would seem that formerly landowners, in building cottages for their labourers, considered that four walls, with a roof on the top, pierced by a small door, and still smaller windows, constituted all that could reasonably be expected. The site was a matter of indifference, so long as the situation was convenient, and it is to be feared that even in the present day landlords, both in London and the country, are given to disregard the health and comfort of those who have to occupy the cottages they build. As an instance, a cottage built by a gentleman in the suburbs of London for his gardener has recently come under the author's notice. The house has been designed regardless of internal accommodation; it consists of two wretched living rooms (about 10 feet square), in one of which is the copper and a sink, and overhead are two bedrooms of the same area, but with very low ceilings, and this is considered in modern times sufficient for a married man, with possibly a large family. The design and construction of houses, and even their ventilation, is without the province of the engineer, but the question of healthy homes for the working classes cannot be satisfactorily accomplished, if whilst devoting

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his attention to providing pure air and water, the essentials of sanitation, the architect does not co-operate with him. The beauty of rural scenery may be greatly enhanced by neatly designed cottages, but first let them be the homes of health, and add the effective exterior afterwards.

The question of ventilation plays a very important part in the health of the community, as well in the mansion as the cottage. Says Mr. Baily Denton: "The removal of vitiated air from, and the regulation of the temperature of, public buildings, such as hospitals and asylums, and of private mills and factories, and the dormitories of large institutions and private dwellings, are objects of extreme difficulty. Up to this time science has certainly not been able to fully master the subject, although a great number of valuable theories have been propounded by experts, and ingenious inventions brought forward."

But the difficulty is greater in dealing with the homes of the peasant, for Mr. Denton observes: "The various contrivances which we see advertised for securing ventilation are only useful when a sufficient provision for air space, and a proper provision of inlets and outlets, in the shape of doors, windows, fire-places, flues, and shafts, are wanting. Every day's experience, indeed, clearly proves that the refinements of ventilation are quite out of place in well-planned private houses, and need only be resorted to where large numbers of persons congregate in special apartments or buildings, or where the arrangements of a dwelling are defective, or where accident has defeated a good design. Every apartment, from cellar to attic, in a private dwelling should command the necessary circulation of air, without the existence of draughts, which are equally resisted by the poor in the cottage and the wealthy in the mansion. The rural labourer will stop up with a wisp of hay the best ventilator his landlord may introduce, if by atmospheric attraction cold air rushes in to take the place of the warm, and makes him feel cold."

With the above pointed remark the author fully concurs, as also with the following opinion, which is particularly appropriate with reference to the home of the peasant: "That in every living room there should be a constant but imperceptible change of fresh for used air, in quantity proportionate to the number, age, and occupation of the inmates."

Drainage.

The question of drainage and disposal in rural districts is one of a very complex nature, involving, as it does, so many conflicting circumstances. Where in towns the populations

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to be benefited are taken by thousands, in villages they are only by tens; and whilst in the former case there is a certain amount of compactness of district and regularity, in the latter the houses are so scattered and inconveniently situated that the engineer, who in this particular is fettered by the question of cost, has no small difficulty to overcome, if really it can even be surmounted. Whatever sanitary works are carried out in rural districts, the present pernicious system of hidden and open cesspits must be abolished, as much on the ground of morality as of health. But it may be asked, how will the evil be remedied, seeing that in many cases a system of drainage in rural districts is impossible, on the ground of cost, smallness of population, and very often physical difficulties? The author is certainly not an advocate for dry-earth systems, as applied to rural populations, although for isolated establishments he admits their efficacy. But these closets may develop into a curse instead of a blessing. The poorer classes will sometimes go out of their way to evade sanitary precautions, and experience has shown that for this class all appliances of this nature must be as simple as possible. Convinced of this, and having occasion to design some ash closets, the author had some difficulty in arriving at a satisfactory result; but in the end he found that, in order to attain the object sought, the action of the closet would have not only to be entirely regulated by the opening and closing of the seat, but the lid itself had to be so fixed at an angle when open, that the moment the seat was vacated it fell down by its own weight, thus placing the matter entirely beyond the chance of forgetfulness. At the same time, as will ever be the case, the arrangement was not proof against wilful mischief.

If possible the sewage and other refuse should be taken by a main sewer away from the houses. In a village of ordinary size the cost of a pipe sewer of sufficient capacity need not be great, and if it be possible to convey the sewage to some point well away from the vicinity of the dwellings, and then to deal with it in land—say allotment gardens—not only would a boon be conferred upon the inhabitants, upon sanitary grounds, but also upon those who might be tenants. Should this, however, be impracticable, an underground tank, with some simple means of ventilation, might at a small cost be constructed in concrete, and the contents might be periodically sold to the farmers for manure. A 6-inch pipe, with adequate fall, will remove the sewage of a great number of houses; and the generality of villages consist of one main street, a road of say half a mile, so that under favourable circumstances such a sewer, with a tank to receive the sewage, would not cost more than 300*l*.

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The author does not condemn earth closets in principle, because really they obey one of the first laws of nature; it is the application that is open to question. First, the cost of reorganizing the whole closet system of a village is a formidable difficulty, whilst admitting the imperative necessity of abolishing open cesspits. But will the substitution of dry-earth closets effect the desired result? The cost of the simplest appliance is 1*l.* 10*s.*, and for general application in villages it is open to an objection at first start. Mr. Denton says: "There is no disguising the fact that the best dry-earth closet is invariably associated with a vapid smell, which becomes extremely objectionable when the closet is not kept properly cleansed. This condition is greatly due to the difficulty which is found in absorbing and deodorizing the whole of the urine by any of the materials used for the purpose." This is the difficulty—cleanliness. However effective the appliance may be, it falls short of its mission by neglect to observe the guiding principles of health. Again, the strong objection—on the ground of public morality—against any removal in a portable form of excreta holds good. Besides, if even we deal with the excreta by this system, we have yet to remove the other constituents of sewage, house refuse, slops, &c.

The water-closet system is the most conducive to proper sanitation, and in comparison with the cost of altering the ordinary privy for dry earth or flushing will not be found to be materially different. If water is not available, then the dry-earth system is the most effectual remedy for the evils. Where a system of drainage for a village is out of the question, then each house should be drained direct to an hermetically closed cesspit, constructed at as great a distance as possible from the dwelling.

Water Supply.

Whatever difficulties may be experienced in the other departments of sanitation, fortunately nature is more favourable in this branch. In many cases the inhabitants of villages derive their supply of water from shallow wells in close proximity not only to their dwellings, but also to the cesspits and other abominations, which cannot but be the source of serious contamination, and effect a baneful influence upon health. Possibly a village pump, common to all, and subject to the infiltration of deleterious matter from the surrounding district, is the best source at command; or a spring in the roadside, which, however pure at its source, is liable to contamination from local causes. Again, some brook may provide

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an ample supply, but of questionable quality, for often it drains through the inhabited district. In many instances there may be close at hand an ample and wholesome supply of water which might be easily available at a small cost. The primary source of water supply in rural districts is undoubtedly the rain collected upon the roofs of buildings, and in the absence of other and better means this may be adopted in preference to the usual custom. It has been ascertained that one-fifth of the total rainfall of the district can be relied on to be gathered into a storage reservoir supplied by land drains, but a larger proportion than this may be collected from the roofs of dwellings.

A cottage covers about 500 square feet of ground, and supposing 22 inches to be the annual rainfall, a supply of 5700 gallons would be the result. An average-sized farmhouse and outbuildings cover about 1000 square feet of ground, and with the same rainfall the roof gives a supply of 11,419 gallons per annum. The roofs of stables, barns, cattle-sheds, cart-hovels, cow-sheds, &c., would cover about 3500 square feet of ground, and collect 39,965 gallons. There is no reason why the roofs of the church, school, and other buildings should not be used as a means of collecting the rainfall, and thus contribute to the general supply; and if an underground tank be constructed of sufficient capacity, a very large quantity of wholesome water may by this means be impounded for the benefit of the inhabitants.

The Baroness Burdett Coutts has at her own expense had constructed in one of her villages in Wiltshire a reservoir for the purpose of receiving the water from the church and schools, and during the dry summer of 1868 as many as 120 buckets of water were counted as being fetched by the villagers in one day. The above facts are quoted from Mr. Wheeler, who, in speaking upon this important question as affecting the Fen districts, where a scarcity of water often occurs, says: "An ordinary village church would cover 7000 square feet, and the schools 1000 more, and these together would yield 91,356 gallons in the course of the year, equal to a daily supply of 250 gallons. This supply would be infinitely better for all purposes than water from ponds or wells." In such localities as the Fen districts, or where it is impossible to derive a supply of water other than from shallow wells or streams of questionable purity, then for dietetic purposes water collected from roofs may be resorted to, and at a very small cost. But the chief point to be attained is that it be removed as speedily as possible from atmospheric influences, and contained in a proper reservoir.

The most common source of supply is a brook or stream

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running through the midst of the village, and which not unfrequently serves as the public sewer. In a small town in Ireland the only available water supply to 900 inhabitants at the present time is from a shallow brook situated in the lower part of the town, and the author has seen the inhabitants taking their supplies from below stream, to where horses and cattle are driven down to water. Upon inquiry as to the cause of this wretched state of affairs, the author was informed that the pump, which was supplied from the same stream (though higher up, and away from the cattle), having got out of repair, the lord of the manor, who had some ill-feeling towards the inhabitants, had not only refused to repair it himself, but had refused to let the inhabitants do so. It is in Ireland that remedial measures are most required, and the facts before stated can be largely multiplied. If a stream running through a village can be dammed back, or a weir placed across it at some point above, at a very small cost (and no real injury to those using the stream as a motive power), a wholesome supply of water may frequently be conveyed by gravitation to the village. In hilly districts small streams abound, and may be impounded at a very small cost. If the physical features of the district are adverse to gravitation, the water can be utilized by means of that simple but beautiful machine the hydraulic ram. This little self-acting engine will lift water to an elevation of 150 feet, and convey it for a distance of 50 or 60 yards with a fall of 10 feet. Messrs. Gwynne and Co., who have an improved type of these machines, state that it will work day and night without any attendance after it is once fixed. It is necessary to have a fall of water to work it, and the greater the height of the fall the more effective will be the machine. In favourable cases it will raise water thirty times higher than the fall working it. These machines can be made to deliver comparatively large quantities of water, and two or more rams may be made to force through the same pipe. Where a continuous stream of water cannot be obtained, a spring, or even rainfall or drainage, may be stored up in a reservoir or dam, and made to work the ram. The cost of a ram, with piping and the necessary appliances, capable of raising from 4000 to 5000 gallons of water per twenty-four hours, would not be more than 400*l*.

Under some circumstances, a well or spring would supply ample and wholesome water, but may be so situated as to be below the point required, motive power being necessary to lift it to the village. Messrs. Gwynne have surmounted this difficulty by improving upon the ordinary machine by a ram being exerted by a stream of questionable quality, and giving the motive power to an ordinary reciprocating double-action pump

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to raise the pure water. It is very often that with such a machine pure water may be pumped, by the flow of sewage through the ram.

For the supply of water from streams there are numerous hydraulic machines, more or less effective, which may be adopted. The turbine is one of the most effective, providing motive power for raising water from the same source. The turbine combined with a centrifugal pump is a very simple and economical means of rising water to heights not exceeding 50 feet. But greater height may be attained by connecting the turbine with force pumps. There are also various types of water-wheels, which however, in the case of rural water supply, are hardly applicable.

Some few years ago the author had to examine into the circumstances of the insufficient supply of water to the small town of Bakewell, in Derbyshire. It had for years enjoyed an ample and wholesome supply of water, and the simple but efficient method adopted is worthy of description. The town is situated upon the side of a hill, forming the valley of the Wye; and on the other side of the valley there exist several springs of the most wholesome water, and at such an elevation above Bakewell as to enable it to gravitate to the town. A simple spring would not however afford a constant or sufficient supply for the requirements of the people, particularly as the landowner below claimed the right to a certain quantity of the water from these springs, which found its way through his estate. This gentleman did not wish to prevent the surplus water being used for the supply of the town, as the springs were so copious as to necessitate a great waste.

By an ingenious arrangement, five of these springs were intercepted and concentrated in a gauge house, in which was fixed a weir, so regulated, that whilst the necessary quantity of water went to supply the estate, the overflow was conveyed to a service reservoir, and served to supply the town. These five springs, although running all the year, varied considerably in their yield; in dry times the whole five were necessary to keep up the required supply, and at others two or three would answer the purpose.

Close to the point of outbreak in the hill-side a small stone sink was made, about 18 inches square at the top and 9 inches square at the bottom, and about 18 inches deep; in the side of this sink was a rose head, connected with the pipe to the gauge house; at the bottom of the sink was a pipe, serving as a waste to the adjoining stream; in order to regulate the supply to the gauge house, a small piece of pipe was inserted in the

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bottom of the sink, and was sufficiently high to cause the water to flow over its top, and thus, in times of drought, ensure the acquisition of all the water rising from the spring. With such simple and inexpensive contrivances, many villages might be supplied with water, situated as they are in close proximity to springs of this nature.

Of course under certain circumstances the only available means of supply, except from roofs of houses, is from wells. Wells consist of two kinds, shallow and deep. Against the former nothing too strong can be said, and equally with the abolition of open cesspits, must the individual shallow wells of the village be closed.

It may be argued that with the abolition of cesspits the injury to the wells will in a great measure be removed; but the ground in the vicinity of the well having been saturated for years by the infiltration of poisonous matter from the privies and cesspits, their removal will effect little or no improvement in the quality of the water. A supply of wholesome water, necessary for the inhabitants of a village, must be taken from a well situated as far away from the dwellings as possible, and sunk or bored down to such a depth as will ensure a standard of purity. There are difficulties in the way, because the moment you have to sink for water, you begin adding to the expense, not only with the source of supply, but the means of obtaining it. Of course in districts where the strata is stone or chalk, the necessity for lining the well is avoided, but in localities where the ground is of a softer nature, the author would advocate that the well not only be lined, but, in many cases, lined with cement.

The Abyssinian tube wells may frequently be advantageously used for small populations. The whole arrangement is so cheap, simple, and effective as to bring it within the reach of any community. A 3-inch tube will on an average yield from 500 to 2000 gallons per hour, depending of course upon the nature of the strata. Water may be pumped from wells by hand power in sufficient quantity to supply a small community by means of a force pump, worked by two men, and capable of raising 450 gallons per hour to a height of 40 feet. The cost of such a pump, including well and other appliances, would not be more than 45*l*.

Again, wind power may be used for raising water, and combined with a horse-power gearing will be found very effectual in districts where steam is out of the question. The cost of one of these combined wind and horse power pumping engines capable of raising 500 gallons per hour, may be approximately

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stated at 110*l*. There are possibly from 101 to 130 days during the year when the power of the wind may be reckoned sufficient to act upon the pumps, and upon the other days a single horse is capable of raising 8000 gallons per diem, which is ample for the supply of an ordinary village. The author does not advocate wind power, or even horse power, where they can be avoided; but under certain circumstances the adoption of such means may be found desirable.

A village of say 400 inhabitants may be amply supplied with 15 gallons per head per day, and if the reservoir is constructed for holding a six-days' supply, it will not be found necessary to pump every day, or for the whole day. A tank 40 feet long, 25 feet wide, and 10 feet deep, will contain 39,000 gallons, and may be constructed in concrete for about 30*l*.; one with wind and horse pumping machinery and a mile of supply pipe would only amount to 250*l*., and who shall say that expense stands in the way of rural water supply?

The application of steam power to rural water supply is rendered deficient from the first cost, the annual expense of maintenance, and the scarcity of fuel. But where such power can be adopted in coal districts, the actual cost of the appliance need not necessarily be great. The cost of steam engine, pumps, well pipes, and reservoir, capable of supplying a population of 400 inhabitants, will not be more than 600*l*.

Whatever difficulties may have been experienced by those interested in the welfare of the inhabitants of rural districts in obtaining the necessary funds for carrying any work out, unless it be by private munificence, as has frequently been the case, there can now be no possible excuse why landowners and owners of residential property should delay any longer this required reform. By the introduction of a short Act during the recent session of Parliament by Mr. Whalley, the greatest boon has been conferred upon rural populations. Under this Act landowners may now charge their estates with the few hundreds of pounds necessary to provide for the health and welfare of their dependents.

At the present time great efforts are being made to convey to London, Manchester, Liverpool, and other large towns, water from districts far distant, and whilst wishing in no way to condemn the principle of providing for populous places as wholesome a supply as possible, it appears to the author that by the extraction of so large a quantity of water as is necessitated, a great injustice is inflicted upon the inhabitants of those districts whence the supplies are taken.

Parliament, in the consideration of application for powers to

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carry out such schemes, is apt to overlook the fact, that the supplying of large towns means a complete drainage of the district whence the supply is taken; and before permission for this is granted, it should be clearly stipulated that the requirements of the inhabitants of these districts so affected should be attended to.

In conclusion, the author would observe that upon health grounds the sanitation of rural districts demands serious consideration; but whilst life is risked by the ravages of disease brought about by the want of sanitation, there is also a great risk, which should be guarded against, viz. loss of life from fire. Equally with external efforts of the engineer, the architect should, by the design of his houses, endeavour to provide free circulation of fresh air. In cottages where the limited space requires that a sink should be inside the house, the drain into which it is emptied should be outside, with proper and simple appliances for adequate ventilation.

Fresh air and pure water, in a cheerful dwelling, will do more to advance the welfare of the labourer than anything else, and it is to this desirable end that the author would direct the attention of those who have the means and the opportunities.

DISCUSSION.

Mr. A. Rigg said that the subject of the paper was divisible into three parts. The first part related to getting rid of sewage matter from houses. The second part was what might be called mainly an architectural feature, relating as it did to the admission of fresh air into houses. The final division of the subject concerned the supply of pure water. The ventilation of houses had been well discussed in a paper read last year. The present paper seemed to point to the notorious fact that architects either wilfully or ignorantly neglected provisions for the supply of fresh air. No one could stay in the country without being struck with the fact of the plentiful supply of fresh air outside the buildings, and the utter absence of it inside them, especially in the case of churches and large buildings. The houses of the working classes were conspicuous in that respect. He was not surprised that the inhabitants of such houses took means to stop up the inlets for the admission of fresh air, for ventilating arrangements seemed to consist only of means for producing draughts, and failed to distribute the fresh air so that it might enter quietly into the room. If that were done properly no one would stop up the inlets, for all could appreciate fresh air.

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The question of water supply was a very large one. He (Mr. Rigg) had been engaged in putting up water supplies for several villages. The hydraulic ram was a very good appliance where the same water which worked the ram was used, but he (Mr. Rigg) preferred turbines and the force pump where the power and supply came from different sources. Whenever the quantity necessary for driving a turbine was insufficient, a small and cheap engine could be put up for doing the work during those seasons when the supply failed; but, as a rule, there was plenty of water for the turbine during three-quarters of the year, consequently the expense of the steam power during the few dry seasons was never a very serious item.

Mr. W. SCHÖNHEYDER said it would have been well if the author had illustrated the principle upon which he considered houses should be ventilated. The subject was a most difficult one, and if the author had studied and mastered it, it would be very desirable to have the results stated. The author had remarked that one great difficulty in the earth-closet system was that of getting the material removed after it had been made use of. He (Mr. Schönheyder) believed that it had been found quite lately to be unnecessary to remove the earth, and that if it was properly dried it might be used over and over again. That was not his own experience, but he had noticed a letter from America to that effect in 'Engineering' of August 24th last. The writer of that letter stated that some earth had been in use for six years. Of course, in a case like that, it was necessary that only fœcal matter should be allowed to mix with the earth.

Mr. S. ALLEN said the author had omitted all reference to the question of dealing with flood waters in winter. He (the speaker), when at Nottingham, had often watched the valley of the Trent during the winter months, and had seen whole districts flooded. It was evident that all the organic matter which had been received into the Trent from the villages was spread over the valleys where the floods prevailed, and would be left there to await the heat of the summer to make it injurious to the inhabitants of the valleys. With regard to the use of turbines, it was not generally known that Eton and Windsor were supplied with water which was lifted by the action of turbines. The authorities utilized the water of the Thames for driving the turbines and lifting the water from the springs or wells and so giving a pressure of about 70 lbs. in the mains.

Mr. VAUGHAN PENDRED said that the subject before the meeting was a very wide one, and might be looked at from several points of view, such as the landowner's, the water-con-

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sumer's, the householder's, the architect's, the engineer's, and the doctor's point of view. To go fully into the subject was impossible within the limits of any paper; but he could not help pointing out that the author went over only very old ground, and ground which they had all been accustomed to for the last eight or ten years. Mr. Usill had called attention to the fact that very glaring defects existed in the water supply, ventilation, and general sanitary arrangements of rural districts, and he had told them that something ought to be done; but he had not told them what ought to be done. With regard to sanitary appliances, there were, practically, at the present moment, no experts, for he (the speaker) believed that the great sanitary problems which were presented to engineers had yet to be solved in a practical and satisfactory way. The author spoke of the ease with which water could be obtained, under certain circumstances, for rural villages, for about 300*l.* or 350*l.* He (Mr. Pendred) would assume the case of a small village which could be efficiently supplied with water machinery for the price stated; and that anyone thought fit to spend 300*l.* in putting up a set of pumping machinery. So far well, but this was not near enough; they had next to think of the maintenance of the machinery and the organization by which the system must be carried out. The machinery would require to be worked, and the benefactor had done only a very small part of the contemplated good. He had given the village a tool, but no means of using it: to supply water in that way it would be necessary to have a species of local authority in every little village. The first cost would be, probably, very small, and could be met at once, but there would be a difficulty in getting the organization. People would not take the trouble of working the system out. That was one of the great sanitary difficulties in small towns. Again, turning to the question of ventilation, he had never yet seen a house, small or large, that was satisfactorily ventilated. Enormous sums had been spent upon the ventilation of the Houses of Parliament, and yet it was a well-known fact that the members on one bench could not agree with the members on another bench as to whether the air should be put on or shut off. In the case of labourers' cottages which were badly situated, possibly under trees where there was no free circulation of air, and perhaps crammed with furniture, the difficulty of scheming any satisfactory means of ventilation was very great. What was really wanted was not a statement that something could be done, and done at a small price, but the interchange of experience from practcial men who had been concerned in carrying out sanitary arrangements.

Mr. JABEZ CHURCH said that the author had treated the

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subject generally in an exhaustive way, but he had not given them any practical details. What he had said about rural sanitation was perfectly true, namely, that everybody neglected it, and that cottages were very badly supplied with arrangements for ensuring pure air and water, and for the removal and utilization of the sewage. The author's suggestion of collecting rain water from the roofs was a very good one, and the plan would be very inexpensive. At present cottages generally had a shallow well dug in the ground for collecting the surface water, close by which would be a cesspool, and probably a pigsty next to that. The result was that the cesspool and pigsty would drain into the well, and pollute the water. That state of things was a disgrace to cottage owners, but until such people saw the necessity of themselves looking into the matter no improvement would be likely to take place. It was not to be expected that cottagers would carry out the improvements for themselves. Cottage ventilation was a somewhat difficult thing, but he thought that much more might be done than was done at present in that respect. As a rule, poor people appeared to have a great aversion to fresh air, and generally kept doors and windows closed. It would be useful if some simple and effective ventilating arrangement were introduced over which the resident could have no control. As to sewage, the problem of what was to be done with it had not yet been satisfactorily solved.

Mr. P. F. NURSEY agreed with the last speaker, and he believed that, unless there was some proper supervision of dwellings, sanitary improvements would fail to be introduced in even much larger houses than cottages. He knew of an instance of a large house in the country in which, at the end of a long corridor, was one of Moule's earth closets, an unpleasant odour from which constantly pervaded the house. On examining into the matter he found that the means adopted to get rid of the smell by a country surveyor who had been called in, only caused its constant flow into the house, for a plate of perforated zinc had been let into the door of the closet in a line with a ventilating window. By stopping up the plate in the door and making a small outlet in the roof of the closet, as suggested by the speaker, the evil was at once remedied. That circumstance showed that superior buildings wanted a little common sense supervision, quite as much as cottages. He should like to know whether Mr. Schönheyder, who had referred to the practice of using the earth a great many times over, could give any additional particulars as to the practice. A few years since he (Mr. Nursey) was at a meeting where a quantity of earth was exhibited by an inventor who claimed this very principle of

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using the earth several times over. The earth did not present any unusual appearance, but did not smell very earthy. In order to show its purity the person who was exhibiting it began to rub it in his hands, and some of those present did the same; but inasmuch as they quickly made a rush for the lavatory the results would not appear to have been very satisfactory. He (Mr. Nursey) believed that after a time the earth must become saturated and cease to exercise those functions which were natural to it in its normal condition.

Mr. SCHÖNHEYDER explained that he had no experience in the use of earth in closets, but he could understand that there was to a certain extent a good foundation for what was stated in the letter to which he had referred. The earth was supposed to act in the same way as charcoal in deodorizing, and its power was limitless if sufficient time were allowed for the oxygen of the air to act upon the matter which the carbon or the earth had taken up. He believed that combustion took place. The fact that a combustion took place when earth was used was proved by an analysis of the earth which had been used several times over. That analysis detected but very little of the fecal matter which had been deposited in the earth. The same continuous action (cleaning by combustion) took place in an oxide of iron filter. In that filter the oxide of iron took up the impurities from the water, and those impurities were subsequently got rid of by the exposure of the material to the atmosphere.

Mr. BERNARD DYER said that Mr. Usill had mentioned one matter of detail which was very often overlooked, and that was the lining of wells. Too much could not be said against ordinary shallow surface wells. He (Mr. Dyer) had been frequently called upon to examine rural water supplies, and he often observed that shallow wells which had been found to be polluted had been replaced by deep wells, the water of which had appeared to be pure at first, but after some two or three years became almost as badly contaminated as that of the shallow wells. The fact was that the common-sense precaution of lining the deep well, to prevent the infiltration of surface-water, had been neglected. Only last week he received a sample of water from a well seventy-five or eighty feet deep, in Worcestershire. The water was an ordinary magnesian water, but the result of the analysis was such as to throw grave suspicion upon its organic purity, and a microscopical examination revealed the presence of decomposing animal and vegetable cells. He made further inquiries, and he found that the drains of the house were within a few yards of the well, and the intervening soil was a loose marl. The well was lined all the

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way down with loose bricks, without mortar or cement of any kind, and the level of the water being considerably below the level of the ground, there was naturally a percolation from the leaky drains.

Mr. SCHÖNHEYDER asked Mr. Usill whether he would corroborate the statement that the largest town in the world, namely, London, in which the largest amount of money had been spent for sewering, possessed a system which was a grand failure.

Mr. G. W. USILL, in replying upon the discussion, said that in a question of the magnitude of that under consideration it was impossible to deal with the subject as practically as could be wished. It was impossible to give illustrations of what might be done with regard to sanitation, because every single village and hamlet had circumstances peculiar to the locality. To try and lay down a hard and fast rule, to be applicable in every case, would probably have raised as much objection as Mr. Pendred had urged to his (Mr. Usill's) not having done so. While he had met with difficulties which had been overcome, at the same time the question of rural sanitation was really involved in much mystery. The manner in which the difficulty of water-supply was overcome at Bakewall, for instance, would be in no way applicable to a place in the Fens, and therefore if he had attempted to give a number of illustrations of what could be done, he should have had a very heavy task. As to ventilation, that was a very difficult subject. He was afraid that they would never be able to pull down the old cottages of the poorer classes, and rebuild them in a better form, but he was satisfied that, at a very slightly increased cost, new cottages might be built, having greater area and increased height. To ventilate a cottage properly the cold air should be admitted at such a position above the heads of the inmates, that it might be acted upon by the warm air in the upper part of the room. He would place the aperture for cold air at say about five or six feet above the level of the floor, and construct it so that it would not admit a rapid current. With regard to earth closets, he should strongly object to anything like the removal of the deposit in pails. As to the use of the same earth for six years, he could only say that it showed a greater depravity in human nature than he thought possible. Mr. Allen had asked why he (Mr. Usill) had not referred to the regulation of the flood-water in winter. The subject of the paper, however, was 'Rural Sanitation,' and it simply embraced matters which could be dealt with for a comparatively small amount. To deal with the flood-water of Nottingham or the district of the Thames would cost many tens of thousands of pounds. It was too large a

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subject to be dealt with in his paper, although flood-waters exercised a baneful influence over the health of villages. A Royal Commission had, however, been appointed, or was about to be appointed, to consider the question of the floods of tidal rivers throughout the kingdom.

He was quite aware of the difficulty of organization which had been referred to by Mr. Pendred. What he had endeavoured to aim at in the paper was to show that it was impossible, under the Public Health Act, or even under the Act of Parliament to which he had referred, to get any one individual to take the initiative; but if people were only educated to understand that they could bring about improvements at a small cost, the rural classes were sufficiently intelligent to see the advantage of adopting them.

The PRESIDENT, in closing the discussion, said with regard to floods that he did not think that they had to be considered in a sanitary point of view, although they gave rise to very great annoyance and did a great deal of damage. The sanitary measures to be adopted in rural districts presented a great number of difficulties. As to what had been said about landed proprietors, that had nothing to do with the question. When any sanitary works were carried out, it was always found that the ratepayers had to pay for them. As soon as the inhabitants of the district chose to constitute themselves a sanitary authority, they could levy rates, and the owners of property had to pay them. At the same time, that fact did not remove the difficulties. For instance, it did not remove such difficulties as Richmond had some time ago to contend with when the fines were increased week after week for noncompliance with the orders of the Board of Trade until they amounted to 10,000*l*. It was idle to talk about applying the water carriage system to a village or small town of two or three thousand inhabitants. In a large town they had not only the appliances and the skill, but they had money as well; but in a little village where the money could not be commanded, the engineer had to do the best he could with a small expenditure. In such a case, the inhabitants would have no water-closet system, and the engineer would be unable to give it to them, because he could not give them the water supply. These were cases which presented themselves to an engineer, and he was bound to exercise his ingenuity in order to provide for them. The system which would suit one town would not suit another, and the engineer's skill was shown in making the best of the condition in which he was placed.

Some years ago, he (the President) was very much opposed to the earth-closet system. Certainly, that system was per-

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fectly incompatible with the exigencies of large towns, but when small villages had to be dealt with, it was questionable whether the method might not be adopted with advantage. In a case which he had to do with some two years ago, he laid out a system of drainage which took away the liquid refuse from the houses and utilized it upon an estate; but for the solid portion of the sewage earth closets were used. That system had been in use about two years, and it had answered on a limited scale very satisfactorily. There must, however, be supervision in such cases, but the water-carriage system needed only general supervision. A system in which frequent and close supervision was needed could be applied only upon a very small scale, but he believed that when it was so applied, it answered very well. He should not go to the length that Mr. Schönheyder had spoken of, and use the same earth for six years continuously; nor did he think that the analogy between the charcoal in filters and the dry earth in earth closets was at all correct. Charcoal only arrested the gases and neutralized their properties; and one argument against the use of charcoal filters was that after a time they became foul, and the filter had to be sent away that the charcoal might be replaced. Of course it was possible that charcoal might become disinfected by contact with the air, although he very much doubted that it was unnecessary to replace it. In the case of the earth closet, the earth became mechanically mixed with the solid excrement, and therefore he did not see how the same earth could last for six years. He did not see how ventilation was to be compulsorily introduced into houses. They could not introduce it into houses without the consent of the proprietor, because that person could always stop up the ventilation when he pleased to do so. Sanitary measures with respect to sewage and water supply could be introduced without the consent of the proprietor; but there was no doubt that English people at the present day were very much opposed to two great sanitary agents—fresh air and pure water.

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November 5th, 1877.

ROBERT P. SPICE, VICE-PRESIDENT, IN THE CHAIR.

TUBE WELLS.

BY ALFRED LE GRAND.

It is now a little over ten years since tube wells were introduced into this country. The first notion came from America, though a contemporary claim has been made from yet another quarter of the globe. The crude idea had lain dormant for nearly two years, and might have done so for many more, had it not come into the hands of Mr. J. L. Norton, whose indomitable energy soon produced the necessary appliances to develop it into an invention of real practical utility, for which three separate patents were taken out.

Public trials of its usefulness were made in London, Manchester, and elsewhere, and as Government was at that time preparing its expeditionary force for Abyssinia, the War Office authorities had their attention drawn to the invention, and with unusual alacrity they ordered trials to be made at Chatham. These trials so satisfied the commandant of the Royal Engineers that he forthwith recommended the authorities to adopt tube wells as part of the equipment of the Corps of Engineers, and they continue to form an integral part of such equipment to the present day. It is needless here to recall the fact of how valuable they proved in Abyssinia, and how, as a matter of course, they were sent to Ashantee.

Incidentally it may be mentioned, as showing what an interest the late Emperor of the French took in all matters of public utility, no sooner had they become known through the wide-spread publicity given to the invention by the press, than he sent over and invited Mr. Norton to bring his apparatus to St. Cloud. Mr. Norton accordingly repaired thither, and in the presence of the Emperor and the Prince Imperial, drove a well. The soil proving favourable, it only occupied half an hour to drive 28 feet deep, and to obtain a good supply of water, both the Emperor and the Prince Imperial assisting in the work.

Most inventions of the present day are known by some

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distinctive name or appellation given to them by their respective proprietors, but this was not the case in this instance, for by a sort of common consent both the press and the public dubbed them "Abyssinian" tube wells, and sometimes "Abyssinian" pumps; the latter can, however, hardly be considered correct, as the invention relates almost exclusively to making wells, while pumps of various patterns are employed in the work, and all descriptions of pumps are applied to them when permanently set up.

Before proceeding to describe the invention in detail, it may not be amiss to correct one or two popular errors which have even found their way into the Government Text Book of Instruction in Military Engineering. One is, that any sort of common gas or other pipe will answer the purpose, whereas specially tough lapwelded tubes are required for the work, in order to stand the hammering and vibration to which they are subjected, ordinary tubes being found to crack in all directions. Another common mistake is that these tube wells can be of no use beyond 30 feet. Hundreds have been driven to much greater depths, and in nineteen cases out of twenty the water from the springs, when tapped, rises to within reach of a suction pump, occasionally flowing over the surface. Where the water does not rise to within reach of suction, special modifications hereafter described meet the contingency.

The process of driving tube wells resembles pile driving, but with this distinction, that while piles receive the blows of the monkey on their heads, the tubes are not struck at all, the blow being communicated by the clamp, which receives the blow near the ground. The tube well as ordinarily used is not intended for piercing rock or solid stone formations, but it is quite capable of penetrating very hard and compact soils, and can also be successfully driven through chalk, breaking through the flints which may obstruct its passage downwards. When solid masses of rock or stone are reached special means of drilling have to be provided for it. When coming upon rock or stone the best plan is to pull up the tube and try in another spot. This applies also when deep beds of clay are driven into, for by going a little distance off and testing again in many cases water will be found.

The mode of operation is as follows: The first, or pioneer, tube A (shown in Fig. 1) is furnished with a steel point of bulbous form, and perforated with holes varying from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch, extending from 15 inches to 3 feet upwards from the point. The enlargement of the point serves to clear a passage for the sockets by which the tubes are screwed together. On to this tube the clamp B is fastened by two bolts at about

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3 feet from the point; this clamp is of wrought iron, lined with steel, and screwed internally, so as to form teeth to grip the tube. Next the cast-iron driving weight or monkey C is slipped on to the tube above the clamp. The tube thus furnished is stood up perfectly vertical in the centre of the tripod or shearlegs D D D, in which it is retained by the latch E. The feet of the tripod should be looked to, in order that they be firmly planted, and do not slip or sink during work.

The whole being now arranged in position for work, the ropes F F are made fast to the monkey and passed over the pulleys of the tripod, and driving is commenced by two men pulling the ropes and allowing the monkey to fall on the clamp. At this point particular attention must be paid to frequently tighten both the bolts equally as the driving proceeds, for the clamp must not on any account be allowed to slip, otherwise the blow of the monkey is in a great measure lost, the result being no good to either clamp or tubes, besides wasting time. As soon as the clamp reaches the level of the earth by dint of repeated blows, the monkey should be raised, and one man, taking a turn of his rope round one of the legs of the tripod, holds the monkey suspended, while the other loosens the bolts of the clamp and raises it about 18 inches, and tightens the bolts again as at the commencement. If the ground be very soft the clamp can be raised 2 feet or more, as it saves the frequent readjustment; if very hard, not more than 1 foot.

In this manner driving is continued until the top of the tube comes below the hole in the tripod head, or top plate. Immediately it reaches this point the lengthening bar (Fig. 2) is brought into requisition by dropping its small end into the top of the well tube. The object of this lengthening bar is to keep the tube steady, and to enable the operator to have a temporary guide for the monkey to slide on, until the well tube has been driven into the ground to within a foot of its entire length. This, as will be readily understood, could not be accomplished by screwing on a fresh length of tube, as the socket joint would not allow the monkey or clamp to pass over it. When driving in hard ground the lengthening bar is apt to rebound, and in so doing it would burr the well tube, but to obviate this a small indiarubber ring, or washer formed of twisted string, is placed at the shoulder.

Before the tube has, however, been driven thus far a hollow iron plumb is lowered into it, so as to ascertain whether water has been reached, or whether earth of any kind has got into the tube. This indicates what depth of earth or water stands

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in the tube. If neither are present the iron plumb will strike plainly on the bottom of the tube; should earth be present, by allowing the plumb to strike on it once or twice, some will adhere to the hollow, and thus indicate the nature of the soil. It should here be mentioned that after the first tube has been driven, the well should be plumbed again as soon as the second tube has been driven, say, three or four feet into the ground, and every two or three feet afterwards; otherwise, by neglecting this, a seam of water may be passed without knowing it. If after more or less driving not more than a few inches of earth, and that of a comparatively dry nature, be found in the tube, no notice need be taken of it; but should it increase to a foot or more, it should at once be removed by the aid of the cleaning-out tubes.

To connect the fresh tube, the monkey is first suspended in the manner previously explained, and the clamp removed from the tube that has been driven and fastened on to the length of tube about to be added to the well, at about six inches from the end of the tube which has the socket, the small end of the clamp being towards the socket. The tube with the clamp on it is then passed through the suspended monkey and secured in its place in the tripod head, and then screwed as tightly as possible on to the tube that has been driven. In fact, the tubes must meet or butt against each other, and the joint altogether must be made so tight that it cannot unscrew in the course of driving. Length after length is in this manner added until the desired depth is reached.

When earth or clay finds its way into the tube while driving, it is removed by means of small cleaning-out tubes, usually ½-inch internal diameter, which are provided in lengths to suit any depth. A sufficient number of these to reach to the earth in the well tube must be screwed together, and each should be carefully lowered into the well tube, all but about six inches, and sustained in this position by tongs while another length is screwed on to it. Care must be taken in lowering these tubes not to let them slip down, otherwise considerable trouble will be caused in recovering them.

When the accumulation in the well tube is of a loose sandy nature, if wet it can best be withdrawn by means of the pump, which, with the reducing socket, can be coupled on to the top of the cleaning-out tubes. When this is the case, before screwing on the pump, the funnel (Fig. 3) should be screwed on the top of the well tube, so that, if necessary, water can be poured down the well tube, when, by pumping, sand and mud will be pumped up, and by continuing to pour fresh water

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down the tube, and pumping up through the small tubes, all the earth can be removed.

When water is struck and stands several feet in the tube, the pump (Fig. 4) can be applied. This is furnished with a broad open top, in order to facilitate the removal of sand, &c., which may accumulate. It requires simply to be screwed on to the tube well with white lead. To start the pump, some water is poured to prime it, and when the air has been exhausted, in all ordinary cases the water will follow. At first the water pumped will be muddy and gritty to a greater or less extent, according to the nature of the stratum. After pumping for a short time, and the water shows signs of clearing, the handle of the pump should be raised high for a second or two; by doing this the bucket will press on to the spur on the clack valve and cause it to open, and simultaneously the tumbler valve in the bucket will be raised, upon which the water will run suddenly down the tube, which a few strokes of the pump will recover; and this should be repeated several times. The result of this sudden letting down the water several times and stopping it before it has got down to the water level of the well, causes the water to force its way violently in and out of the perforations at the bottom of the tube well, disturbing the mud and fine particles of the stratum around the perforations. If this has been done properly, the water will again have become muddy and thick, as at first, and steady pumping will, in a short time, bring up all the mud and fine particles which have thus been disturbed.

The object of this stirring up of the mud is to thoroughly disintegrate the soil and clear away all the finer particles in the immediate vicinity of the perforations, leaving the larger stones and grit to form a natural filter around the tube well. Fig. 5 shows a tube well that has been driven, and the soil disintegrated around the perforations in the manner described. This process should be repeated several times, until it is found that the mud ceases to come up, for upon the careful carrying out of this greatly depends the quantity of water which the well will yield, and the ease with which it can be pumped. The neglect of this will, in many soils, cause sand to come up some time after the well has been made, and will diminish the yield, and also the ease of pumping. Moreover, in some strata, if this be not properly done when the well is first made, the sand will accumulate in the tube well, and tend to stop the supply altogether.

When first starting to pump a well in the manner just described, should the sand accumulate so fast as to prevent the

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pump from raising the water, the cleaning-out tubes must be employed, in order to pump up all the sand clean out of the tube, and when this has been done the pump can again be screwed on to the tube well, when in most cases it will be able to pump up the rest till the well has been cleared. If at first the water only comes with great difficulty, it must not be concluded that no supply can be got; on the contrary, in nine out of ten cases, by a free use of the tilting action of the pump, the compact earth will be broken up and loosened, so that after half-an-hour, or it may be several hours' pumping, it will produce a perfectly free yield, where at first it was difficult to get half a supply, and a little perseverance will be amply rewarded.

Fig. 6 shows the plan adopted by the Royal Engineers, dispensing with shearlegs on account of their weight, and in their place employing simply a pair of pulleys clipped on to the tube itself.

When from any cause it is found necessary to withdraw a well, it may be accomplished by fastening the clamp to the tube a few inches from the ground, and making a fulcrum of the monkey, prising up the tube with the lengthening bar or any available lever, lowering the clamp after each successive lift.

Another plan, when the tube is very firmly imbedded, is to put the monkey on the pipe the reverse way to what it is when driving the well, and then fasten the clamp on the tube also the reverse way, about two feet above the monkey. A man on each side pulls up the monkey against the clamp, and thus drives it upward out of the ground. Fig. 7 shows this: the work which would otherwise be very laborious, is, by a simple contrivance, made quite easy. The whole weight of the monkey is supported by two stout indiarubber springs, similar to those used to close doors. All the workmen need do is to give the momentum to the monkey by pulling the ropes and cause it to strike upwards against the clamp. When the tubes are withdrawn they may be re-driven in another spot. In withdrawing the tubes each joint must be unscrewed as it is raised to the surface. Before attempting to drive the tubes afresh they should be examined to see that they are perfectly straight. Bent tubes should never be driven, as they are not only apt to bend worse, but if they come on anything very hard they are liable to spring and not drive at all.

In cases where the water level is found to be but a few feet below the reach of a suction pump, the simplest plan is to dig down 5 or 6 feet and take off the top length of tube, and, after having cleaned up the well with the usual pump, a long barelled pump (as shown in Fig. 8) reaching to the surface is

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attached to the well tube, and the hole that has been dug is filled up again, as the lower box of the pump can always be got at from the surface at any time it may require seeing to.

Where, however, the water level stands some considerable depth below lifting reach, the plan adopted (shown in Fig. 9) is as follows: When the first tube has been driven into the ground, the working barrel A, consisting of a short length of tube lined with stout brass, together with the conical brass seating B, is screwed on to the tube which has been driven; next, the washer C is placed on the working barrel. This washer is to prevent the brass lining from jarring up out of its place while being driven. To this working barrel are then added fresh lengths of tube, driven in the usual way, until the barrel reaches just below the water level. The bucket D, connected with suitable lengths of rods, is lowered into the working barrel and attached to the lever in the pump head as shown.

In clearing up these deep wells, owing to the comparatively large size of the tubes employed, the up current of the water when pumping is not of sufficient velocity to carry up with it the heavier portions of grit, &c., which, consequently, accumulate in the barrel. To overcome this difficulty a sort of plunger pump of a novel description has been designed (Fig. 10 shows a section). The plunger box A is furnished with double cup leathers placed in reversed positions, i. e., one cup downwards and the other upwards; a tumbler valve is fixed at the bottom, the tubular rod which carries the plunger box communicates with it, and when the lever of the pump head is raised, the water, grit, &c., instead of passing slowly up the long well tube, is forced rapidly up the small tubular rod, from whence it is expelled at the outlet B, and by this means all the heavier particles can be effectually cleared out of the tube well.

It may be observed that Mr. Norton's patents passed into the hands of Messrs. Le Grand and Sutcliff, of Magdala Works, Bunhill Row, London, a few years back, and this firm has recently patented an entirely new method of driving tubes applicable for wells, and for other purposes, which the author will now briefly describe.

In practice it has been found that when driving in very hard bands of strata, immediately the point has penetrated through them the driving becomes quite easy again, irrespective of the depth that may have been reached. For instance, it is quite common for a tube to take many hours driving through an obstruction of three or four feet, met with, say, at 20 or 30 feet below the surface, and subsequently driving at four times the pace when reaching possibly double or treble the depth. From

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this fact, it is quite evident that the first tube with its point accomplishes the whole work of penetration, leaving the tubes that follow practically no resistance to overcome.

Instead, therefore, of striking the tube at or about the surface, as in Norton's method, and having to transmit the blow through any length of pipe, varying according to the depth driven, Le Grand and Sutcliff's arrangement delivers the blow immediately above the point at the bottom of the tube, in fact, exactly where the blow is wanted. This is accomplished in a very simple manner by using an elongated weight, shod with steel, which passes down the inside of the tube. To this weight is attached a long rope, which is pulled by hand and allowed to fall, striking upon an even surface provided at the top of the bulbous point; this is the most simple form of working on this plan, and is shown in Fig. 11. Fig. 12 shows a more convenient form of working, which consists of a short shearlegs, the head of which serves as a guide for the tube, and from this head rise two tubular uprights, to carry a pulley, over which the rope travels, and which can be worked either by hand, or other power.

One feature of the new system is, that it does away entirely with the risk of bending the tubes when they get on to anything hard; on the contrary, the tendency is to keep them perfectly straight, and the tubes are not damaged in any way.

Fig. 13 shows a plan (suitable for tubes of large calibre) for shutting out any sand, which might get in and impede the blow. It consists in providing the weight with an outer casing, in which it can freely slide up and down; the shoulder provided on the weight enables it, when withdrawn entirely, to bring the casing up with it.

Another plan is shown at Fig. 14. This acts upon the pneumatic principle. The bottom pipe, about 4 feet long, without perforations, is smooth drawn and slightly smaller in its internal diameter than the tubes which follow it; the driving weight is hollow, consisting of an outer and an inner tube, the annular space being filled with lead. Near the bottom of this driving weight, which is steel shod, a rope or other suitable packing is fixed, so that it acts as a plunger. At the top of the inner tube of the driving weight is fixed a valve, which allows any air to escape as the weight drops. When the weight is lifted, a partial vacuum is created beneath it. This increases the labour of raising the weight, but the additional labour thus expended is nearly all returned in the augmented rapidity with which the partial vacuum causes the weight to fall.

This plan of internal driving is found to be very applicable

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for driving tubes of large diameter, as the tackle required is so simple and inexpensive; it also commends itself most favourably for driving under water, as by its means a tube can be driven at the bottom of a well which is more or less full of water. The process is not by any means confined to well-sinking purposes. Iron piles can be driven most effectually, particularly where there is a great depth of water, it being quite practicable thus to drive piles 50 or 100 feet below the surface of the water. On a smaller scale the plan is also well adapted for driving telegraph posts with rapidity for military or permanent purposes, as well as for tubular posts for wire or other fencing.

The uses to which the smaller sizes of tube wells are adapted are very various; to a great extent they supply an important want of the present day in furnishing pure water for domestic use, and thus replace the old dug wells, which, in most rural districts are found contiguous to cesspools, and with few exceptions are more or less contaminated by sewage. In numerous instances by driving one of these tube wells, some 16 or 20 feet below surface springs, a pure supply can be obtained, for these tubes are found to perfectly shut off all communication from the impure water in the upper seam. To give an instance, out of many hundreds, at Brandeston Hall, in Suffolk, the dug well, which supplied the household, being found to be impure, thereupon a tube was driven, and after passing a very compact bed of clay, some 20 feet thick, chalk was met with at 36 feet, and an abundant supply of perfectly pure water obtained.

The smallest-sized wells are also advantageous for manufacturing purposes, for supplying moderate-sized boilers with feed water, not only in rural districts, but in towns supplied by waterworks, thus saving heavy water rates. Many are thus in use for similar purposes, even in the very heart of London, springs being found to exist in many spots when it might have been expected that deep sewers had drained away all the land springs overlying the London clay.

As it is not uncommon for an 1¼-inch tube to yield from 500 to 600 gallons per hour, constant pumping, contractors in erecting large buildings find them very useful, both for supplying their engines and for mixing mortar, and on the completion of the contract they are taken up ready for use elsewhere; this feature of being readily transportable from place to place renders them invaluable for railway contracts, and especially so for exploring expeditions, Sir Samuel Baker and others, having employed them in Africa and elsewhere for that purpose.

Another use to which they are daily put is for testing ground to ascertain how deep water lies below the surface, to test the quality and quantity obtainable before sinking larger perma-

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nent tube wells. It will readily be seen how valuable such a rapid means of obtaining such a data becomes, as before purchasing land for any purpose, the primary question of water supply can thus be settled. The firms of Messrs. Mann and Crossman, and Messrs. Truman, Hanbury, and Buxton, among many others, availed themselves of this medium to test sites of land before purchasing them for building their branch breweries at Burton-on-Trent.

It will also be seen that this principle of testing land is not confined to water purposes, for it is equally adapted for testing for foundations more expeditiously than any other known plan. In fact, tube wells must daily become more and more an indispensable adjunct to the plant of engineers and others dealing with land projects generally; and the only wonder is, that such a very simple invention should not have seen light many years sooner than it did.

Within the limits of a short paper like the present, it is not possible to do more than very briefly describe the smaller-sized tube wells and appliances, those of larger diameter requiring more complicated apparatus. These and the mode of dealing with large supplies of water, and also with various strata and bored tube wells, will form the subject of a future paper.

DISCUSSION.

Mr. C. HORSLEY inquired how deep Mr. Le Grand could sink the tube wells, and what was the size of the largest pumps employed.

Mr. VAUGHAN PENDRED said that his experience of tube wells was limited to one in which the tube was driven into a limestone soil to a depth of 15 or 16 feet. There was an abundant supply of water, and the water in the district generally was exceedingly good, but at the time that he last saw the well it had been worked for a month, and had been constantly pumped, but the water was quite undrinkable. It was of a dark brown colour, and apparently strongly tinged with iron. Whether corrosion had taken place in the pipes through their being of wrong material he did not know. He would like to have the cause explained. He would also like to have some explanation as to the way in which the tubes were kept straight. It appeared to him that if there was not a great deal of care taken in setting up the shearlegs in the first instance the sinkers might start with the tube crooked. But apart from that, if they came into contact with a boulder the point of the tube would be deflected, and it seemed as if the tube would be subsequently bent continuously, and the effect would be

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much like that of driving a bent nail. He assumed, from the author's explanation of the exceedingly ingenious means used for keeping the holes open, that there was, practically, no trouble incurred from the stopping up of the bottom tube. He should further like to know what had been done in the London basin in getting water. Were there any instances in which a tube well had been driven with success through a soil where the clay was within a foot or so of the top?

Mr. SCHÖNHEYDER said it appeared that all difficulties had been so well overcome that the tube well was a great success, and it no doubt proved very useful. But he would like to know how the men proceeded in arranging the tube if the water was very deep down. It was stated in the explanation of Figs. 9 and 10 that the barrel A was screwed upon the tube B, and after that the other tubes were screwed on and driven down. But, unfortunately, they were not aware at what depth the water would be reached until after the well was driven, so that it was impossible to know beforehand where the gunmetal barrel was to be placed, whether it would be necessary to employ a barrel, or whether it would be sufficient merely to use an ordinary surface pump. Were there any means of inserting a barrel low down in the tubes after it had been found that the water was too deep to be drawn by ordinary suction? The arrangement for driving the tubes, at Figs. 13 and 14, was very ingenious, but it was open to the objection that if there was water in the pipe that water would prevent the blow from taking effect.

Mr. T. H. MARTIN asked whether, in using the system shown in Fig. 11, the author had ever driven through any flints in the chalk, say beds two feet in thickness, such as existed in the London district.

Mr. A. LE GRAND stated that almost the first trial which was made of the tube-well system by order of the Government, was made at Chatham through chalk and flints, and it happened to be at a place close to where there was a cutting exposing its formation, so that an observer could stand below and see every row of flints through which the tube had to pass. The pipes were driven down 30 or 40 feet, and they passed through several beds of flints, and every time they came upon one of those beds the progress was almost stopped, and the monkey rebounded. The point of the tube being made rather sharp, when it came upon a flint it cracked it after a few blows had been given, just as a needle would crack a piece of ice. Although his paper related only to the smaller-sized tubes, the question of deep wells being reserved for a future paper, he might state that tube wells had been driven into the chalk to a depth of upwards of 100 feet.

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Mr. T. H. MARTIN asked whether the system of driving shown in Fig. 11 could be used in cases where there were beds of flints 2 feet in thickness, such as he had met with in boring at Barnet.

Mr. LE GRAND stated that that question properly belonged to the subject of deep wells in the London basin and elsewhere, with which the paper at the next meeting would deal. Without, however, trenching upon that subject, he might say that the tubes were not capable of going through any dense mass like a perfectly compact bed of concrete. They would go through ordinary flints which were found in the chalk—say from three to five inches in thickness. When a dense mass was to be passed through, a hole must first be drilled.

Mr. J. BERNAYS observed that when the tube wells were first brought out, they were quite a surprise to the profession, and no one could believe that the water could be drawn up even after it was reached. As a proof how necessary it was to look carefully to the pipe joints, he knew an instance in which a small well of 15 or 16 feet was driven in a gravel soil, but no water could be obtained, although about 50 feet off there was another well of about the same depth, and which gave a good supply. Upon examination, after digging down by the side of the driven tubes, it was found that the tubes had been allowed to slip aside at the joints in the driving, so that there was, really, no continuity throughout. It was necessary to withdraw all the pipes except the lowest part, to put a joint to the lowest tube and connect it with the pump. The tubes were 2 inches in diameter, and the suction tube connecting the bottom tube with the pump was an inch tube. The method shown in Fig. 11 was very elegant and ingenious, but, at the same time, there had also occurred to him the objection which had been urged by Mr. Schönheyder, which was that if water got into the tube a satisfactory blow could not be given.

Mr. C. HORSLEY said he did not think the brown colour of the water alluded to by Mr. Pendred could have been caused by the corrosion of the iron pipes or from any defect of the pump. With regard to working depths, he (Mr. Horsley) could see no reason why the wells could not be worked at a depth of 250 feet as easily as at one of 50 feet. With regard to the driving of the well in the manner shown in Fig. 11, he thought that the speakers who had said that the presence of water in the tube would be an obstacle had overlooked the fact that in Fig. 14 there was a casing provided on purpose to keep out the water.

Mr. PENDRED said that when he alluded to the colour and quality of the water which was produced by a tube well, all he

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did was to state a fact and ask for an explanation of it. He did not propound any theory as to the cause of the water being unfit to drink.

Mr. P. F. NURSEY said that as one who had witnessed some of the earliest experiments with the small tube wells upon their introduction into this country ten years ago, he was exceedingly gratified to observe recently at Messrs. Le Grand and Sutcliff's works, tube wells of very large diameter. That was evidence that remarkable progress had been made with the tube wells which had been developed from a few small pipes—useful enough in their way—to a very complete and comprehensive system, which was being practically carried out on a large scale. He would offer a suggestion with regard to one part of the process of sinking the wells as described in the paper. When the hollow plumb was dropped in the tube it was allowed to fall heavily in order that it might pick up if possible, by grasping, some of the soil beneath it as an indication of the strata. It occurred to him that if some tallow was put in the hollow of the plumb, it might be made to lick up any loose matter upon which it fell much more readily and with greater certainty than if the plumb were simply dropped down without the tallow, as it might be dropped many times before any of the débris would clog the hollow, for that was what took place.

Mr. E. W. BROOKING said that there was within 100 yards of his residence a tube well, the water of which so abounded in sand that it was unfit for consumption. The gardener pumped two or three hours a day for the purpose of clearing the tube and water, but without success. Another well of the same kind within a mile of his residence at Potter's Bar had been abandoned for the same reason. If that defect could be obviated, he saw no reason why tube wells could not be used in rural districts for obtaining a supply of water. He had a very large district under his control, and he should be pleased to see them introduced if they were not liable to the objection of being blocked up, or the water so charged with sand as to be unfit for use. He should be glad if Mr. Le Grand could explain the reason of the nuisance.

Mr. SCHÖNHEYDER asked the size of the smallest tube with which the monkey could be used, and also what was the largest quantity of water which had ever been drawn from a tube well of any size?

Mr. LE GRAND, in replying upon the discussion, said that the object of the paper was more particularly to give the details of the principles upon which the work was done, and to state the capabilities of the smaller-sized tubes. With respect to the

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case mentioned by Mr. Pendred, in which the water yielded by the tube well continued of a brown colour, in spite of pumping, he could only say that it was quite impossible for the tube to be the defaulter. There were many districts in which pure water was found in abundance, but where occasionally what was known as a "pot" of a different soil would be met with. At Burton-on-Trent, for instance, there were beds which yielded splendid water, from which most of the brewers brewed their ale, and yet here and there beds of peat were found, and the water pumped up from those beds was very dark and thick. At Messrs. Handyside's works, at Derby, a tube was driven for the purpose of obtaining drinking water for the men. The first water obtained was apparently pure and as clear as crystal, but in a few minutes it turned dark and tasted like ink. There was no accounting for such things. In the case of wells in private use, the water was sometimes allowed to remain, perhaps, twenty-four hours in the pipes without being pumped, and it thus got discoloured from contact with the iron, and it might be necessary to pump up a pailful or two in order to clear the pipes of the water which had been standing in them. The purer the water, the greater was its tendency to take up the oxide from the pipe.

As to the deflection of the tube by its being driven upon a flint or boulder, of course much depended upon the manner in which the tube struck the stone. If the end of the tube came upon the stone so that it did not get a lodgment, or if it struck the stone obliquely, the probability was that the tube would be deflected. Captain Clarke, R.E., had mentioned that at Annesley Bay the soil was full of enormous boulders, and the tubes had to be driven several times, in some cases, before they could be got down; and some of those which were driven down and fulfilled their purpose, when withdrawn came up zigzag, showing they had been deflected more or less, but still had reached water and yielded an ample supply. When a tube became deflected, and there was still a great depth to be driven, the best plan was to pull up the pipe and drive it somewhere else.

With regard to the stopping up of the perforations, the number of holes drilled in the tube was such that the total area of the holes was equivalent to about four times the area of the section of the tube, so that that allowed for 75 per cent. of the holes being completely stopped up, and yet sufficient openings being left to admit as much water as the tube could take up. In sinking deep wells, it would be impossible to go so deep as 250 or 300 feet in the London basin by driving alone. They might speak of the London "clay," but what was generally so termed, often contained many other things.

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In some parts of it there were beds of shells 3 or 4 feet thick, and as hard as any concrete. The shells in question were those of oysters and other bivalves. Beneath the plastic clays, and before the Thames and Woolwich beds were reached, he had met beds of stone which were like the French burr of which millstones were built. When the sinkers came upon masses like that, it was impossible to drive without first cutting a hole through them.

With reference to the barrel shown in Figs. 9 and 10, the question was asked, "How are you to know when to have the barrel ready?" If there were other wells in the neighbourhood, the depth of the water would be known. When there was no other well near, no one could tell at what depth water would be found. At one place it might be met with at 15 feet, and at another place at 50 feet. But having ascertained where the water was, they pulled up the small tube, and then drove one of larger calibre, with the working barrel to suit the water level.

He had been asked how deep he had been able to drive with the new process. That process, however, was so new that they had not done anything with it publicly. What had been done consisted of only a few private trials. In the case of the first experiment, the bottom tube was perfectly plain, about 4 feet long, forming a smooth barrel. The perforations did not occur until the second tube. The driving weight was furnished with a packing, consequently it fitted tightly in the first pipe and the water and grit were kept above, and could not in any way interfere with the striking of the blow. By this arrangement the blow was always given perfectly dry, and the partial vacuum added to the intensity of it.

There was another and still more simple method, though it, perhaps, was adapted to larger pipes, and that was the plan where the rod worked inside a case, the case being sealed at the bottom, so that the blow was driven in a perfectly dry place.

He had recently driven a tube down at Maidstone about 39 feet deep through sand and water into chalk. It was driven with a very rough driving rod down the inside of an ordinary tube well, perforated at the bottom, and there was nothing, practically, to interfere with its working. They were not confined in using the weight to pulling it up with a rope. Rods might be used, and they would also serve to increase the intensity of the blow.

A very serious question had been touched upon, with regard to wells choking up with sand and becoming useless. They might drive a pipe in a sandy soil, pump it, and get it apparently clear; and then, in a day or two, the sand might

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cave in, and fall into the tube in consequence of a cavity having been formed, and holding up for a certain time. When that happened the process of clearing must be commenced *de novo*. Special means would be required in dealing with a soil of that kind. It was simply a question of the well being driven by a person who understood the matter. There were means expressly designed for setting right anything that might occur during the work, and there were filters for shutting out the sand; but those matters did not come within the province of his paper that evening.

The smallest tube which it had been attempted to drive was of the size exhibited as a model, about $\frac{7}{8}$ inch external diameter; but for practical purposes it would be unwise to use anything smaller than $1\frac{1}{4}$ inch. That had been found the minimum serviceable size. He had known a tube of that size to yield 900 gallons of water per hour. The yield of water was not so much governed by the size of the tube as by the nature of the soil.

The CHAIRMAN (Mr. R. P. Spice), in closing the discussion, said that the invention of tube wells was one of great ingenuity and importance. A friend of his had purchased a residential estate near Chelmsford, and when he entered into residence he found that the water was not fit to drink, although there was an abundant supply. He introduced a tube well, and obtained a supply of good water. The system which had been described related to wells of small diameter, and consequently of shallow depths, intended chiefly for domestic purposes, and not to such as were suitable for the supply of towns and villages. On a future occasion, however, the author had promised to go into the latter and wider branch of the subject. So far as the small wells were concerned, he (the Chairman) thought he was not saying too much in stating that, from all he had now gathered and all he had previously heard on the subject, they had been of very great advantage in enabling persons, in all parts of the world, to obtain readily a supply of water at a small cost. Taking water from an impure source could be avoided by going below the impurity, to a spot where the water was not contaminated by drainage or filtration. The appliances had been improved step by step, until they had now reached a very advanced stage. The ingenuity which had been brought to bear upon them deserved every commendation.

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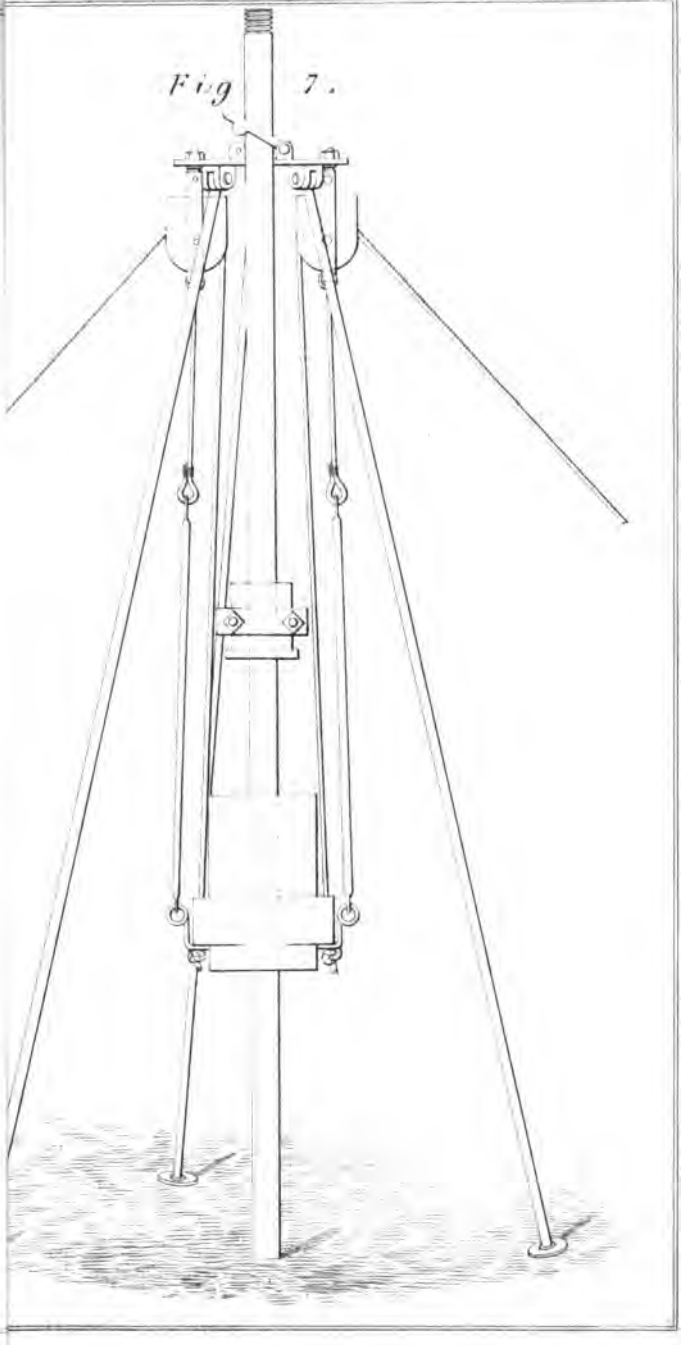

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Fig. 13.

Fig. 14.

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December 3rd, 1877.

THOMAS CARGILL, PRESIDENT, IN THE CHAIR.

TUBE WELLS FOR LARGE WATER-SUPPLIES.

By ROBERT SUTCLIFF.

In the paper read at the last meeting of the Society the details of mechanical appliances for driving tube wells were fully described. The subject for consideration in the present paper is the use of tube wells for large supplies of water, and the methods of dealing with various strata. In favourable soils, such as coarse grit, gravel, chalk, and some marls, a 3-inch tube well will yield from 1500 to 2000 gallons per hour. The engineer at Messrs. Allsopp's Brewery stated that with a portable steam pump he filled a cask containing 100 gallons in one minute from a 3-inch tube well, which is at the rate of 6,000 gallons per hour. Such a supply from that diameter of tube must, however, be considered as quite exceptional. The water in this instance was drawn from gravel, and the well was 30 feet deep.

In laying down apparatus for large supplies, instead of increasing the diameter of the tubes beyond 3 inches, it is found preferable to sink a number of wells and couple them together by horizontal mains, placed some 2 feet below the surface to protect them from frost and changes of temperature, as shown at Fig. 1. The mains are usually cast-iron flange pipes, with branch pieces placed at each tube well. As will be seen by Fig. 1, a bend is attached to each branch piece, and this bend is coupled on to the tube well by means of a flange, which is screwed on to the tube well corresponding with the flange of the bend. Should increase of supply be required at any time, more wells can always be added to the group by removing the blank flange and prolonging the mains to additional wells. The tube wells are placed about 20 feet apart, more or less, according to the nature of the strata. Steam pumps are attached to the mains, so that one pump draws from ten or fifteen wells. It will be seen that by this system of coupled wells a very large

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area of ground is drawn from, very far exceeding that of any dug well in existence.

In this way most of the leading breweries at Burton-on-Trent get the bulk of their water-supply, the greater part of which is used for refrigerating purposes, as it is found that water from tube wells is of very uniform temperature, generally about 51° or 52°, and is unaffected by the hottest weather. Messrs. Allsopp and Sons have thirty coupled 3-inch tube wells, from which three pumping engines draw 60,000 gallons per hour, or 600,000 gallons per day. Messrs. Bass and Co. have twenty-five coupled wells, from which they obtain about 500,000 gallons daily. Thus in one town two brewers are obtaining a daily supply sufficient for a town of 40,000 inhabitants, at 25 gallons per head per diem. Other brewers in Burton have coupled wells in use for smaller supplies.

The soil in all the above cases is sharp gravel or sand, and but few of the wells exceed 30 feet in depth, as at about that depth the hard red marl, with bands of gypsum, is met, into which it is impossible to drive more than a few inches. Although many of these wells are within a stone's throw of the river Trent, the quality, level, and temperature of the water in every case differs from that of the river water. The first group of wells was sunk at Burton in the year 1868, and has been in satisfactory use ever since that time.

The waterworks constructed a few years back at Carmarthen, in Wales, derive their supply entirely from ten 2-inch tube wells. 'The Welshman' newspaper of June 12th, 1874, referring to the town waterworks, said: "The inhabitants of Carmarthen ought to be thankful that they are not as other people—in the matter of water-supply. Whilst at Pembroke Dock water is being sold in the streets at a penny per gallon, and a bayoneted sentry is placed at the only remaining spring, to prevent the waste of water, the people of Carmarthen—thanks to the tube wells—have an ample supply, and of excellent quality. For some months the new engine at the new waterworks has been going day and night, and the supply, so far from being diminished, has increased considerably in the past week or so. On Tuesday afternoon there was a trial test, in order to ascertain the quantity of water pumped into the reservoir in a given time, the two receiving buckets containing each 154½ gallons. The trial went on for half an hour, when it was found that the pumps had been throwing water at the rate of 9000 gallons per hour, the engine at the time making from fifty-six to sixty strokes per minute. This trial was of the most gratifying character, and must set at rest all doubt as to the success of the new waterworks. The recent analysis shows that

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the inhabitants of Carmarthen are being supplied with water of excellent quality, wherever it comes from."

It is said that when these tubes were first sunk at Carmarthen, a member of the corporation thought it so impossible that ten little tubes of only 2 inches diameter could supply the whole town, that he took a chair when the pumps were first started and announced his intention of not moving until the wells were pumped dry. After four hours the alderman gave in, and expressed himself much puzzled as to where all the water came from. At the annual meeting of the Town Council held at the Guildhall, Carmarthen, in November, 1874, the Mayor, before vacating his seat, reviewed the work of the past year, referring with particular satisfaction to the success of these waterworks, which had only cost 2200*l.*, and had yielded during the previous summer, which was a very dry one, 1,344,000 gallons per week, or about the quantity required to supply the whole town. The cost of pumping had been 156*l.*, and the average cost would not exceed 150*l.* per annum. He contrasted those facts with the state of affairs at Tenby, where 12,000*l.* had lately been borrowed for the water-supply. The death rate of the town had recently decreased from 21 to 17.

Coupled wells have been put down at various places in England: among others may be mentioned two 3-inch wells at the Solway Hematite Ironworks, in Cumberland, which enabled the proprietors to effect an annual saving in water rate of between 300*l.* and 400*l.* per annum, and three 3-inch wells at Messrs. Charles Price and Co.'s Oilworks, near Belvedere, in Kent, which provided them with an ample supply of clear water, and enabled them to avoid the expense of carrying mains into the Thames, and then filtering the water to remove the mechanical impurities. In this case the water obtained from the tube wells was brackish, but as it was only required for refrigerating purposes, the saltness was of no consequence. The Thames water would have been useless in summer, owing to its high temperature.

Before sinking a set of wells which it is intended to couple together, the ground is always tested by means of the small 1¼-inch tube well, so that full information may be obtained regarding the strata at each spot and the exact depth that it is necessary to go. This saves the larger tubes from unnecessary wear and tear, and enables the engineer to have each well the proper length, thus avoiding the cutting and screwing of tubes on the ground. Each 3-inch well is pumped until the water comes from it perfectly clear previously to making the connections with the mains. It is advisable to put a stop-valve in the mains between the pumping engine and the wells, as if from

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any cause the pump should lose its water, it is apt to cloud the wells.

The proper treatment of the various soils is most important in making successful tube wells. An inexperienced or unskilful man will, in many cases, fail to make a well, where one properly trained will obtain an ample supply. One of the most troublesome soils to deal with is sand. In some localities water is found in strata composed entirely of fine sand, in which the ordinary tube well, with the usual sized perforations would soon become choked, and as fast as the sand is pumped out with the aid of the small cleaning-out tubes, it will flow in at the perforations. The author heard of some Dutch sailors who drove a tube well on their coast and pumped up so much sand that the earth above caved in, and the stout Netherlanders all fell into the hole together. To overcome this difficulty, a special perforated tube is employed, termed a sand-tube. This is so constructed as to present a large surface of fine interstices, forming a screen, which prevents all the coarse sand from entering the tube, admitting only the water and the finest particles, which are easily pumped up with the water. The pointed tube is perforated for a considerable distance at its lower end, so that the total area of the perforations may be, say, ten or more times the sectional area of the pipe. Within this tube and extending along the perforated part an inner tube also extensively perforated is inserted, and around it horsehair cloth is wound in many convolutions, so as entirely to fill the outer tube. The horsehair so applied effectually stops back the sand, but it allows the water to filter into the inner tube, and from thence it passes into the main well tube, and is drawn up by the pump. In the employment of this sand tube, it is sometimes advantageous to make use of a vacuum chamber, and this is done by introducing a suction tube into the tube well, as shown at Fig. 2. It will be seen that the inner or suction tube is made with a top flange, which is shut in between the top of the tube well and the pump, so that when the water in the well is lowered a partial vacuum is created in the annular space outside the suction pipe.

This form of sand tube has been successfully used in many quicksands, and perhaps with the most notorious success on the Leicester race-course during the Royal Agricultural Show of 1869. The weather at the time was particularly sultry, and the water from the tube well was so remarkably cold and clear that the stand was mobbed by crowds of thirsty sight-seers, in consequence of which a space was railed off and a trifling charge made for each glass of water. At the close of the show the money thus collected was handed over to the Leicester Hospital, and amounted to the respectable sum of 23*l*.

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One drawback to the form of sand tube described is, that the ground has first to be tested with the ordinary tube well, which has to be withdrawn to enable the sand tube to be driven in the same spot. Other sand tubes therefore have been designed which can be dropped down the ordinary tube well without withdrawing it. These sand tubes have perforations of different sizes with the object of adapting them to the various kinds of sands. If a sand has a number of coarse particles, and a smaller proportion of fine, it is advisable to use a sand tube with perforations of such size as will allow the fine to pass, but keep back the coarse. In this way a filter bed is formed, through which the water will flow much more freely than if the whole of the sand were kept back, and after steady pumping the fine sand ceases to come into the well. There are, however, some water-bearing soils which are so fine and floury in their nature that to shut them back would also exclude the water. Much thought was expended and many experiments tried in such soils; ultimately the following plan was adopted with success:

A tube well was driven at Chislehurst into an extremely fine sand, and it was found impossible with the horsehair strainer to get any supply of clear water. The tubes were withdrawn, and the point screwed off, and the open pipe driven into the same hole. The pump was then screwed to the top of the tubes, and four or five barrow-loads of sand pumped up. Previously to doing this, however, six barrow-loads of good, clean, sharp grit gravel were brought to the spot. The pump was removed, and down the tube, which was only 1¼ inch internal diameter, as much gravel was forced, ramrod fashion, as filled up the cavity made by the removal of the sand. The open tube was then withdrawn and a pointed and perforated tube driven into the gravel bed thus formed. A coarse sand tube was dropped into the well to keep back the grit, and upon again attaching the pump, the water came freely and rapidly cleared. Fig. 3 shows the bed of gravel inserted in the manner described. In consequence of the success of this well, another was sunk on the same estate with equally satisfactory results, and these two wells have now been in use over two years, and within the last few weeks a third has been added.

At Orpington, in Kent, what is known as a blowing sand, was dealt with somewhat similarly. Owing to the nature of the sand, a cavity could not be made in it as in the previous case. A hole six or seven inches in diameter was therefore bored and piped down with large tubes, until several feet of the quicksand had been passed through. The quicksand was removed from the pipes with an ordinary boring shell, and gravel was rammed down, the large tubes gradually withdrawn as the work pro-

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gressed. The small 1¼-inch tube was then driven into this vertical gravel bed, as shown at Fig. 4, and a good well made which gave a supply of about 200 gallons per hour. Clay was rammed tightly over the gravel to prevent drainage contaminating the well. The large tubes were entirely dispensed with before completing the work.

Another method of introducing a gravel bed was employed in a dug well at Lewisham, in Kent. The dug well became dry during last summer, and to obtain a fresh supply, a tube well was driven below the bottom of it, and water in a fine silver sand obtained. Gravel was thrown into the dug well, and by its weight gravitated to the spot from which the sand was being drawn. The operation of pumping out the sand and replacing it with gravel was continued until the water became entirely free from sand, and was so plentiful that two pumps were attached to it, and the next house supplied from it. This method has not yet been tried for large supplies, but several engineers, and among them some members of this Society, have expressed a very favourable opinion of the feasibility of carrying out waterworks on a large scale in localities where quicksand has hitherto baffled all attempts at making wells. One great advantage of this gravel filter is its imperishability, and of course if the area of the gravel bed be made sufficiently large, the velocity of the water is not sufficient to bring the grains of sand within the area acted upon by the pump, and it is not therefore likely to become choked, like a filter of small dimensions.

From some gravel a few grains of sand may at times come into a tube well, and yet not in sufficient quantity to necessitate a sand tube. A grain of sand, however, getting under the clack of a pump may cause it to lose water, and when a pump attached to a tube well loses its water it causes agitation in the soil around the perforations, and other grains of sand come to keep the first one company. If no worse harm be done, annoyance is caused by having to prime the pump before using it. To obviate this a top strainer is placed immediately below the pump, with a flange to retain it at the top of the tube. This effectually protects the working parts of the pump from injury, and can be easily got at if necessary.

The greatest depth that a tube well has been sunk (within the knowledge of the author) by simply driving, is 116 feet, at Deal, in Kent. The strata was brick-earth, gravel, and chalk, and an interesting illustration of how perfectly the tube well isolates the spring it draws from was afforded. The tube, of 1¼ inch internal diameter, was driven down 18 feet, and water of brackish quality was found. At 45 feet fresh water was

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obtained, and on driving to 116 feet water was pumped as salt as brine. Thus the presence of fresh water between two salt springs was ascertained, and a supply for a steam flour-mill and domestic purposes was secured, and although some three years have passed, the water remains as fresh and pure as ever. At Sprowston Hall, near Norwich, a 2-inch tube well was driven, and passing through contaminated water, reached a spring in the chalk at 111 feet, which analysis proved to be of unusual purity. At Strasburg, a few years back, a tube is said to have been driven to a depth of 120 feet.

As an exceptional instance of the rapidity with which tubes can be driven in a favourable stratum, it may be mentioned that at the Gillingham Cement Company's Works, in Kent, a 1¼-inch test tube well was driven 83 feet in a single day; a sample of water was taken for analysis, and the well withdrawn in about the same time. At the Thames Haven Company's landing wharf a test well was driven 53 feet in one afternoon.

When a stratum proves of too dense and compact a nature to drive into, or if rock or stone be met with, the impediment is overcome by making a bored tube well. Wrought-iron tubes (generally perforated up for a few feet) of great strength, and joined together by means of steel sockets, are employed, and instead of a pointed end, the tube is open, but is provided with a strong steel shoe. The method of boring is mainly the same as that employed in ordinary artesian wells, but in certain strata, such as sandstone rock, hollow boring rods are used, and the pulverized stone is pumped up through the rods, which obviates the withdrawal of the chisel and lowering of a shell to bring up the débris. The mode of pumping and development of supply is, however, entirely peculiar to the tube-well system, and the coupling of wells together is also applicable, and in many cases advantageous.

In putting down a group of bored tube wells it is advisable (particularly where the water runs in seams) that the pipes should be carried down to different depths, as by so doing they are less liable to rob each other than if the length of the wells was identical. They may be alternated, say, one well 150 feet, the next 100 feet, and the third 150 feet again, and so on. For town supplies, and if land be difficult to obtain, the tubes may be driven along the roadside and the mains laid in a subway, and merely space secured sufficient for the pumping station.

The importance of the pump being directly connected with the tube wells is very great, as by the removal of all atmospheric pressure on the water in the tube the effort of every stroke of the pump is to draw the water to the tube, and to

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prevent a vacuum fresh water flows to the spot. Now, when water is drawn from an open well or bore pipe, the level of the spring is merely maintained by gravitation; there is no drawing of the water into the well, it simply percolates into it at the pace that the particular stratum will allow it. Further, the disintegrating action of the pumps caused by the tilting described in the previous paper, opens all the fissures round the tube well and adds very largely to the supply. The object of the perforations in the bored well tubes is to enable the disintegrating action of the pump to have full effect, as the jets of water sent out laterally are found to produce more marked results than the vertical movement of a column of water in the bore hole. As the boring progresses the pipes are driven as deep as the hole has been made, or, if possible, a few inches lower. This practically closes the pipe, and allows the perforations to be utilized in the tilting of the pumps, and such a drag is put on that particular part of the bore hole that channels of supply are opened, which the pump, if acting on a more extended surface, would leave undeveloped. If this process be repeated from time to time by means of a second perforated pipe carried down inside the permanent well tube, it will be known exactly from what part of the bore hole the water really comes, and the supply is augmented and developed in detail, and is finally all utilized upon the withdrawal of the internal tube. Fig. 5 illustrates the process just described. Bored tube wells have been already made to depths exceeding 300 feet, and through limestone and other rocks, and are capable of being made to any depth that an ordinary artesian boring can reach.

It may be interesting to refer to some particular instances. At Messrs. Warwick's Brewery, Newark-on-Trent, a bored tube well of 5 inches internal diameter was made about 95 feet deep through red marl, bands of stone, and gypsum. The supply upon first connecting the pump did not exceed 1500 gallons per hour, but after four days' steady pumping and tilting 6000 gallons per hour were obtained, and came with the greatest freedom. The pumping engine was worked by steam, and the tilting was managed by a tap in the suction pipe, which at frequent intervals admitted air and caused the rapid alternate vertical motion of the water in the tube well, which is so effectual in disintegrating the water-bearing stratum.

At Messrs. Truman, Hanbury, and Buxton's Brewery, Burton-on-Trent, two 5-inch bored tube wells were put down through hard marl and gypsum to a depth of 114 feet, and coupled together, yielding an ample supply. At Birmingham one 5-inch tube well was bored through red marl 200 feet to the

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sandstone, and enough water obtained to supply the Lower Grounds, Aston Park, with its ornamental waters, fountains, and extensive gardens. The proprietor of the Lower Grounds stated that by the use of this tube well he was enabled to entirely dispense with the town water, and thus save an annual rate of 300*l*. Coming nearer home, many tube wells have been sunk in the London basin.

At West Thurrock, in Essex, about 19 miles from London, the Tunnel Portland Cement Company is pumping from two 5-inch tube wells, about 80 feet deep, 220,000 gallons of pure and clear water per day of ten hours. At Messrs. Lawrence and Wimble's Cement Works, Northfleet, one 5-inch tube well yields 60,000 gallons per day. The aggregate daily supply, therefore, of these three wells is 280,000 gallons. They have been regularly pumped for about two years, and the supply shows no sign of diminution. The cost was under 100*l*. each. Hence, for less than 300*l*. a constant daily supply of 280,000 gallons has been obtained. The 16,000,000 gallons required by the Board of Works' scheme could therefore, under similar favourable conditions, be obtained at an outlay of about 18,000*l*. The water level in the tube wells at West Thurrock and Northfleet stands at only some 14 feet below the ground level, and the pumping engines are on the surface. The fact is important, as indicating that the scarcity of water in the heart of the London basin is owing to the porosity of the chalk being insufficient to conduct rapidly a supply to meet the present demand of existing wells in the metropolis, and not to any want of water in the outer circle of the basin. At Bermondsey and other places, bored tube wells have been put down in the chalk to a depth of 200 feet, and at Anerley to a depth of 370 feet; but in the latter case, although the diameter of the tube was 7¼ inches, a free supply could not be obtained owing to a fault of grey chalk, which contains but little water.

From the supplies given by tube wells of various diameters, it will be noticed that the quantity obtained does not so much depend on the size of the tube as on the nature of the strata. The tube well is really a suction pipe drawing from nature's reservoir, instead of from a limited receptacle in the shape of a dug well. For this reason it is far better to sink a series of comparatively small wells, and thus draw from several points, than to attempt to drag an enormous body of water to a single spot.

It is said that the first tube well consisted of a pointed bamboo driven into the earth, and the pump was a "nigger" who sucked the water through the pores of the cane. Now, we see factories, breweries, and towns deriving from them enormous supplies, and it is not improbable that coupled tube

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wells in the chalk may furnish the solution to the London water supply problem, and give the capital of the empire a constant supply of pure sparkling water, instead of the doubtful liquid that has hitherto been furnished from Father Thames and kindred sources.

DISCUSSION.

Mr. W. SCHÖNHEYDER said he understood Mr. Sutcliff to say with regard to Fig. 2, that that arrangement of the internal pipe was supplied specially for cases where a large quantity of sand was met with.

Mr. R. SUTCLIFF said the object of that arrangement was to make a more elastic draught on the water.

Mr. SCHÖNHEYDER said it was a very simple arrangement, and one which he thought ought to be applied to most tube wells, especially if the depth was great. It was well known that it was a difficult matter to use a long suction pipe for a pump, simply because there was a large quantity of water to put in motion at each stroke of the pump. He knew several cases in which failure had resulted in the attempt to draw water from a long distance, though not necessarily from a great depth. The tube shown in Fig. 2 was simply a vacuum vessel. It ought to be applied to most tube wells whether they had sand in them or not. In some waterworks with which he was connected some years ago, they had a suction pipe 30 inches in diameter nearly 500 feet long. It worked perfectly satisfactorily, and there was no difficulty experienced with it.

Mr. SUTCLIFF said that the arrangement spoken of by Mr. Schönheyder had been applied to other tube wells besides those yielding sand.

Mr. A. F. WILSON said he should have liked to have had some remarks from the author of the paper with regard to the peculiarities of the different water-bearing strata. The public had heard lately of Messrs Meux's deep-sinking experiment at their brewery in London, but they had not heard the reasons which led to the abandonment of it. He was himself connected with waterworks where the supply was obtained from a horizontal culvert running several hundred yards, and a question had been raised about the extension of the culvert. It seemed to him that a tube well might be a much more convenient and probably much cheaper way of getting the supply increased than the extension of the culvert. The works were upon the upper greensand, and the London clay was immediately beneath. Close to them the gault cropped up.

Mr. C. HORSLEY said from what he had heard of tube wells,

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he believed that they would be found cheap and economical for those who could not sink deep wells, but after all he considered that in most cases 112 or 113 feet depth would yield only surface water. The water might be good at that depth. The author had stated that the supply of London could be effected by means of tube wells for 18,000*l.*, with a supply of 16,000,000 gallons a day. If that could be done the Metropolitan Board of Works should be prevented making the large expenditure which was in contemplation. He would ask the author whether he really meant what he stated, that he could obtain a supply of pure water of that quantity, or whether he would not have to go farther away from London to the outskirts of the basin where it cropped out, for instance, in the neighbourhood of St. Albans, Watford, and the Colne Valley. He thought as regarded the London basin, that the depth of it would be so great, that the tube wells would be of no use. He was connected with a company near London which spent almost as many thousand pounds to get water as the author proposed to expend to supply London, and they could get no good water. If they had employed tube wells, they would have had surface water. Sewage was found in the water taken from a depth of about 200 feet. As to the supply of London, he was afraid that the metropolis would be without water for some time if it was to depend upon the tube wells. With regard to the tube wells themselves, he was much pleased with the way in which the makers had overcome the difficulties arising from the presence of sand. The pumping out of sand, and the filling up the hole with gravel was a very excellent idea. He would ask whether, when a depth of 115 feet was reached, there was a pump at the top, or whether buckets were lowered? At a depth of 150 or 160 feet the difficulty would be to prime the suction pipe, provided the water did not rise to the proper height, and they might be without water for a week in a town if anything went wrong with the priming. He could quite see that if the water rose up to a certain height, they would have the water at the top.

Mr. J. Glynn said that mention had been made of the tubes being bored into the chalk. He had had some experience of the chalk, having been connected with the London and Watford Waterworks, which proposed to supply a portion of London with water from the chalk in the valley of the Colne. In that place they did a great deal more than even the tube wells had done. They got out of a comparatively shallow well, 12 feet 6 inches diameter, and four bore tubes, 1,800,000 gallons a day, and they did not pump merely for one day, but for nearly six months, which proved that they had the water beneath them. It was very easy to assume that they had a large quantity of

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water simply from pumping for a few hours, but it was not always the case that such a large quantity was present as was assumed. On the other side, they often obtained a much larger quantity of water than was supposed, by the opening out of fissures which were connected with each other. He did not see any special novelty about tube wells, as far as the chalk was concerned, because they were obliged to bore through it, and through certain strata under ordinary circumstances. The mode of boring mentioned by the author of the paper was only one kind of boring, which was not indigenous to these wells at all, as Kidd, he believed, used it years ago for the same purpose. Then it had been said that these wells could be used for the supply of towns with water. It seemed to him rather extraordinary that that proposal should be mentioned, because although the tube wells might be all very good if they got into the gravel or into the sand, at the same time engineers did not want to get into the gravel or sand. That had been proved over and over again. Where it was possible, they kept away from all those impure sources. Why were they shutting up all their wells in London? Why were they doing the same in Vienna and Berlin? Berlin was entirely on the sand. They were shutting the wells up because of the contamination by sewage. In Essex they sank some wells in the gravel, and it was found that other wells were affected two miles off. In a town there was always a large number of houses built over with cesspools, besides the sewers and gas pipes in the streets, and these must certainly make the water impure. His statement was borne out by the results which had been obtained from analyses of many town wells. Some five-and-twenty years ago there was a very extensive series of experiments made in Surrey for the purpose of obtaining water from the Surrey sands. That scheme was abandoned, because in the first place it was found that the water was not as pure as it ought to be, although it came from a district where there was no sewage infiltration from cesspools, and because it was found that they would not get the quantity of water that they required. He could not see that there was any great advantage in tube wells, and he believed that an ordinarily sunk well would be much more important and useful. If they sank a well deep enough, they could sink bore holes, or drive adits out of it, and therefore obtain a large area of water-bearing surface, and could also form a reservoir which would give time for the water to accumulate in readiness to be pumped for twelve hours a day.

The advantages of the tube wells for great depths had not been clearly proved to his mind, but for surface or house wells they were useful, where only a few gallons per day were wanted.

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At Price's Oil Works he understood that the water obtained by the tube wells was so bad that they did not intend to continue to use it, and they were proceeding with some other means of supply from a purer source. At the Vinegar Works in Southwark Street they had four tube wells, and out of those four they got six thousand gallons an hour, but the water was simply gravel water of the most impure kind. He thought that it was a very wide statement to make, to say that London could be supplied by tube wells at a cost of 18,000*l.* If the author had said something like 180,000*l.* he believed that it would be nearer the mark, and then only from a bad source. It must be taken for granted that the sum stated in the paper included pumps and fittings. Certainly the necessary quantity of water could not be got directly under London, though no doubt around the London basin there was almost any amount of pure chalk water.

Mr. F. DEARE said that in South Africa the tube wells had done most important service. They had there naturally a very dry soil and hot climate, and the tube wells had been driven with perfect success. The misfortune was that they had a class of people there who were not very prone to take to improvements. Tube wells, however, were gaining ground, and in most arid places where they had never known any water before, they had been able to raise any quantity of the purest quality.

Mr. GLYNN asked whether the water to which the last speaker referred had been analysed.

Mr. DEARE replied that the wells that had been driven had been chiefly driven in the country districts, and not in the neighbourhood of towns. He, however, knew of one or two being driven in towns. In one instance the well was close to the seaside, and the other was inland, but both places were free from everything that could interfere with the purity of the water.

Mr. J. GLYNN said that some time ago he had to report on a case in Buckinghamshire in which tube wells had been used. He made some experiments, and had one of the tube wells put down in a field into the sand overlaying the Cambridge and Oxford clays for the purpose of ascertaining what sort of water could be got from it. On examining the water he found that it actually contained urine. That impurity was supposed to be due to there having been a cattle-shed on the spot several years previously. He supposed that the urine had become so infiltrated into the sand that the quantity of water which had been going out was not sufficient to purify the soil up to the present moment.

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Mr. T. PORTER said that he had not gathered that the author of the paper seriously proposed to supply London with water by means of the tube wells. The paper had been exceedingly to the point, and a very valuable and interesting one. If 218,000 gallons of water per day could be obtained for an outlay of 100*l.* the system must be a very economical one. No doubt it was impossible to get pure water from every source and from all strata, but still it could be got from many of the sources which the author had mentioned. Tube wells presented a very simple and effectual means of obtaining an ample supply of water for many purposes.

Mr. V. PENDRED asked Mr. Glynn what was the depth which he would assume as that which would furnish pure water. For instance, in the case of the well which Mr. Glynn referred to, and which had been contaminated by cattle several years before, at what depth could pure water have been obtained? In other words, what depth of filtering stratum would have been necessary to remove all the impurity from that water and render it drinkable? In London the inhabitants drank water which was generally considered to be exceedingly impure, and yet the death rate of London was not very high. While he agreed with Mr. Glynn to a considerable extent, and believed that it might be pushing tube wells a little too far to attain a depth of 200 or even 180 feet, still, on the other hand, provided it could be shown that tube wells could be sunk to a depth of 40 or 50 feet and yield a supply of water which was as pure as any which was now supplied to London, then what would be gained by sinking the well 500 feet, or deeper, or even constructing an artesian well at five times the cost? Engineers might condemn tube wells too hastily, and no doubt the proprietors laid themselves open to that if they pushed their system beyond its legitimate place. But the fact was that they must have water, and in very large cities they were compelled to have not such water as they would like, but such water as they could get. If it could be shown that they could get better water by means of a sunk well than by means of a tube well, let them of course have a sunk well, but he did not think that the quality was materially affected one way or the other by the nature of the well.

As regarded the supply of London with water by tube wells, he agreed with Mr. Porter in thinking that suggestion was not seriously intended. Perhaps, however, the idea in the mind of the author of the paper was, that if London was to be supplied by means of wells, according to a recent proposal, he could put down a tube well for 100*l.*, while a sunk well which would accomplish the same result would cost 500*l.* He (Mr. Pendred)

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could not say that reasoning commended itself absolutely to his own mind, for they had to deal with questions of pumping which were of quite as much importance as the mere question of getting the water.

The pumping out of the sand and filling up the holes with gravel was one of the cleverest things he had ever heard of, but he should really like to know something about the pumps which would go on pumping sand apparently for ever. He had never seen such a pump. In fact, there seemed to be something antagonistic between pumps and sand. He had not seen any definite statement of the cost of putting down the large tube wells. He would also ask whether the tube wells had been used for the purpose of increasing the supply of water from vertical wells in the way of adits. It seemed to him that if the tubes were driven nearly horizontal they might act as feeders.

Mr. J. GLYNN said that there seemed to be some misunderstanding between Mr. Pendred and himself as to the depth from which he (Mr. Glynn) should advise drinking water to be drawn. At Watford the water rose to very near the surface, and better water was not to be found. His antagonism to tube wells applied simply to those cases in which they were in gravel or sand, and the water in them was not generally found at a depth of 180 feet. In London it was met with within 12 feet of the surface. At Messrs. Potts's the tube wells were 20 and 30 feet deep, but the water level was 11·6. That showed that the gravel was not very far from the surface in that case. He still maintained that water taken from gravel or sand was impure in the neighbourhood of large towns. He did not mean that the wells ought not to be used in such places as Abyssinia, for instance, where water could be obtained from the sand, and where water must be had whether it was good, bad, or indifferent.

Mr. JAMES N. SHOOLBRED asked the author whether he had any information as to the length of time during which the tube wells continued to supply pure water. One of the many applications to which the tube wells had been put was to obtain a supply of pure water from beneath a polluted water-bearing strata, such as a bed of gravel. In some cases where they had been so placed, although pure water had been brought up for a time, the water had at length become contaminated from the water of the upper strata finding its way down the outside of the tubes. In the mode ordinarily adopted for driving a tube well, it was not possible to place a collar or packing of impervious material round the tube, at the base of the polluting strata, and so to prevent the polluted liquid from

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following down the sides of the tube. That was rendered more easy by the percussive action of the monkey, which tended to crush the strata through which the tube descended, especially in the case of chalk, and to form a passage through which the water could pass down from above.

The arrangement mentioned by the author for grouping tube wells together with horizontal pipes was no doubt ingenious, and offered certain advantages, inasmuch as it secured a large area to draw from at a comparatively small cost. At the same time the great benefit urged by Mr. Glynn in favour of a sunk well must not be overlooked; that it formed a reservoir for the collection of water during the time that the pumping was not going on. No doubt good service had been done by the tube wells, and a supply of pure water had been, to the speaker's knowledge, obtained by their aid when by other means it would have been only possible to have got water at considerable cost and delay.

Mr. P. F. NURSEY said Mr. A. F. Wilson had asked why the deep well boring at Messrs. Meux's Brewery had been abandoned. The reason was that there was no water to be found, nor was there any probability of water being obtained there by continuing the sinking. It had been supposed that a copious yield of pure water could be obtained from the lower greensand, should it be found to exist under London. Messrs. Meux had proved the greensand to be there, and the water not to be there, except in small and therefore useless quantities. By the aid of the Diamond Rock-Boring Company they sank down through the chalk to the upper greensand, which was reached at a depth of 811 feet from the surface, and was found to be 28 feet thick. Water was not found there, and the boring was continued through the gault for 160 feet, when a bed of coprolite about 6 inches thick was passed, having 4 feet 6 inches of limestone beneath it. The lower greensand was then entered, and as soon as it was tapped water rose to the surface. The yield, however, was comparatively small, and the greensand proved to be 66 feet thick. Beneath it the bore entered the palæozoic rocks, which consisted of mottled red and green argillaceous and micaceous shales. The boring was continued for a depth of 74 feet, and was then abandoned at a depth of 1144 feet from the surface at the level of Oxford Street, which at that point was 85 feet 7 inches above Ordnance datum.

Mr. F. W. HARTLEY said Mr. Glynn had made some remarks with regard to the quality of the water obtainable by the means of tube wells, and that supplied to London. He (Mr. Hartley) was not one of those who regarded absolutely pure water as the best for drinking purposes. Mr. Glynn objected to water

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drawn from sand or gravel, and referred to the advantages of filtration and softening, but he seemed to have forgotten that filter beds were made of sand, which would no more remove the whole of the organic impurities which the water drawn from the Thames contained, than would the gravel or sand into which a tube well might be sunk. Analyses of London water were constantly being made, and doctors talked to an alarming extent of moving organisms and of organic contaminations, but he was by no means made uncomfortable. He had seen the process of water softening carried out at Canterbury, and the water was certainly as pure as anyone could desire, but he doubted whether the inhabitants of Canterbury would be particularly benefited in health by drinking water of such unnatural softness and purity. Doubtless they might save something in soap, but he feared that would only be at a sacrifice in physique.

Mr. C. HORSLEY reminded Mr. Hartley that the sand which was used in the filter beds was washed from its impurities, while in the wells the same sand would be used over and over again.

Mr. GLYNN added that the filtering sand was not contaminated by sewage matter.

Mr. A. RIGG said that a few months ago he had occasion to have two tube wells sunk in the south of London for supplying the condenser of a steam engine, and it was found that any quantity of water could be pumped, but they yielded also a large quantity of sand. There seemed to be several separate water bearing strata; the first which was reached yielded an excellent quality of water, but there was not very much of it, but as the tubes were sunk they passed through the pure water strata, and came upon a more abundant supply, which rose to within three or four feet of the surface, and seemed quite clear, but possessed an offensive smell. Except for the quantity of sand brought up, that water was exceedingly suitable for condensing purposes from its uniformly low temperature, although it was quite unsuitable for domestic use. He thought that the arrangement of an artificial filter formed by removing the sand and replacing it with chalk was most ingenious. Tube wells were evidently fulfilling a very excellent purpose, but they could not be used everywhere.

Mr. SUTCLIFF, in replying upon the discussion, said he would first refer to the question of water in the lower greensand. In putting down a tube well for Earl Brownlow, at the village of Eddlesborough, Buckinghamshire, they went through gault, and at a depth of 290 feet got a supply of water in the lower greensand. That well had been supplying the village for nine years, and the pump had not required so much as a fresh

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bucket leather. In that case the pump was 78 feet below the surface, and the pump rod worked in a 3-inch tube. The quality of the water was very good.

The cost of tube wells varied very much with the strata, but the cost of some had been quoted in the paper. It did not matter how deep the tube well was, so long as the water level was within lifting reach. It was not hard to pump a tube well when that was the case. Mr. Glynn had spoken of the quality of water obtained from gravel. The tube well of course did not alter the chemical quality of the water; it was not a filter; but if a tube was driven forcibly into the earth the area through which the contamination could run down was very small compared with the large area of a dug well. All the joints of the tubes were made water-tight, and no contamination could get into the tubes themselves.

Allusion had been made to some wells in Southwark. Those wells were put down not to obtain a supply of water for drinking but for other purposes, and the quality of the water did not matter. He would mention that the price given as that of the tube wells at Thurrock did not include pumps. It was simply for the wells themselves. The depth to which such wells could be carried was not limited. He was now making some wells at a depth of 600 feet, but in some cases pure water might be obtained at a depth of 30 feet. If they went through a thick bed of clay, they would naturally get pure water. At Greenwich he found the water to be contaminated with sewage at a depth of 70 feet. The purity of the water at any particular depth depended entirely upon the nature of the strata passed through by the well. In the wells at Thurrock the water at present obtained had been found to be pure. If it was necessary to go deeper they might go 400 feet, but if they went to that depth they would not get the same quantity of water. As they went deeper the chalk became denser and harder in its formation, and bore less water. When once they got into the grey chalk they would find very little water.

Mr. Pendred had observed that the quality of the water was not materially affected by the well. The case in point which he (Mr. Sutcliff) had mentioned in his paper, was a very fair illustration of that. In driving the well they found brackish water at the top; but as they went farther down they came into a fresh spring, and for two years the water remained perfectly fresh. That was a very fair proof of the tube well shutting out the surface water. He had been asked what kind of pump it was which had pumped up sand. It was described at the last meeting. The only ill effect which which had been produced by the sand was to cut the leathers up, but when a

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well was completed no sand would come. It was only in the process of making a tube well that sand gave trouble. The strainers which he applied to the tube wells would prevent any grit getting into the pump when the well was completed.

With regard to the cost of making large tube wells, a 5-inch well 200 feet deep, at Birmingham, had cost 150*l*. It saved 200*l*. a year water rate, and yielded 3000 gallons an hour.

He agreed with Mr. Glynn as to the gravel in the neighbourhood of large towns being contaminated, which it was, unless there was a thick bed of clay above it. He (Mr. Sutcliff) was no advocate for shallow wells for the supply of towns situated upon gravel; but of course in some villages where the drainage was properly effected they could get a supply of good water out of the gravel.

With regard to lake-water supplies, he agreed with Mr. Hartley, who said he did not like a chemically pure water. He had heard that a chemically pure water, such as they had at Glasgow, was very bad for children. It contained no lime for forming bone, and the children became ricketty. Thames water could be passed through filter beds of gravel and sand, but that mechanical filtration would not remove the chemical impurities, and if Thames water was chemically impure through sewage being allowed to flow into it, it would remain in the same condition after the filtration.

In answer to Mr. Shoolbred's question as to whether the water would remain permanently pure he would only say that if the strata were of a nature to keep out contamination from the surface, the well would remain pure. At Burton-on-Trent the brewers were very particular; they were constantly analysing and taking the temperature of the water, and they asserted that the quality of that derived from the tube wells was very different from that of the water of the Trent, although the river was so near the wells. The chances of any contamination going down the outsides of the tubes were very small, because the earth was denser round the tube than it was before the tube was driven; indeed it was one of the strongest recommendations in favour of tube wells that they so effectually shut out surface contaminations, and for that reason they had the approval of high sanitary authorities.

Mr. SHOOLBRED said he thought that was not the case when the tube wells were driven through chalk.

Mr. SUTCLIFF said that if they puddled chalk they could make a pond upon it, although chalk was so porous. In the case of the tube well the water was drawn out of the earth itself, and certainly that must be more secure than any artificial reservoir which formed a receptacle to collect contamina-

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tion. There were some soils in which the water came so slowly that a reservoir was needed, but it was very certain that three or four thousand gallons an hour was not merely the contents of a tube, but must come directly out of the earth. When water was drawn out of the earth by a tube well, the creation of a vacuum was commenced, and the water immediately rushed up to supply the tube. In fact he knew by practical experience that they could get a much larger supply from a tube well than from a dug well. Mr. Rigg spoke of some wells which were 20 or 30 feet deep and in which the water was bad. He (Mr. Sutcliff) was very sorry for it, but, of course, as he had said before, a tube well would not alter the quality of the water.

The PRESIDENT, in closing the discussion, said that there appeared to be some little confusion between the abstract principle of the advisability of obtaining water at shallow depths and the particular means to be adopted for obtaining such water. Anyone at all acquainted with the ordinary sanitary statistics of large towns was perfectly well aware of the fact that water for drinking purposes ought not to be obtained from mere superficial depths. A slight confusion had also arisen in discussing the question of the quality of the water with regard to the method of obtaining it. He (the President) took it that the quality of the water at a certain depth was altogether independent of the method of obtaining it. If it was originally impure it would be impure when it arrived at the surface, no matter what mode was adopted for bringing it there. He would draw attention to the remark made by Mr. Shoolbred, that impure water from an upper stratum might percolate down the outside of the tube and so find its way into the pure water at the lower stratum. There was nothing incongruous in that idea, because, even in the case of horizontal drain pipes, it was often remarked, that as much water ran outside the pipes as inside. If that was the case with horizontal drains the maximum effect would be produced when the drain was vertical.

The President remarked that he considered the method which had been described for obtaining water at shallow depths was a most ingenious, rapid, and economical means of effecting the purpose. The principle itself must not be confused with the method of carrying it out, and although in the case of large towns it was indispensable, in a sanitary point of view, to go to great depths for pure water, there were certain circumstances under which pure water could be obtained at shallow depths, and might be safely used without fear of contamination. There were numerous cases in which barracks, asylums, and other

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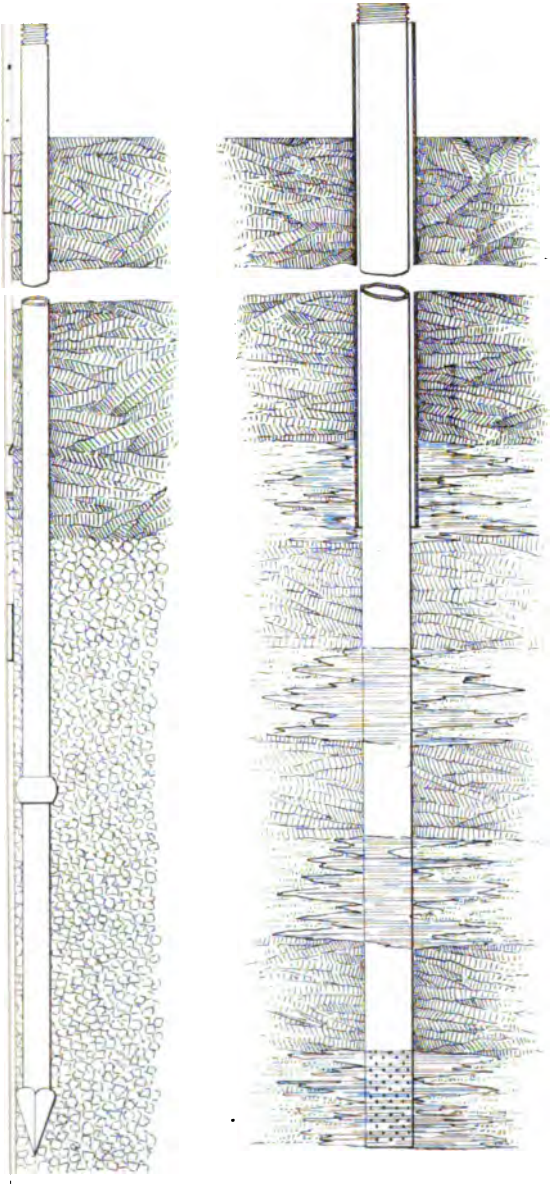
ig. 4.

Fig. 5.



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large establishments were concerned, and where any expeditious method, such as that of tube wells, was of great value for obtaining water. Such cases would furnish examples for the proper application of the invention. It was impossible to state to what extent the application might be carried. The author of the paper had said that he had in contemplation the driving of a well to the depth of 600 feet. With regard to the contamination of water at that depth, he, the President, had been informed on good authority, that water had been found contaminated with sewage at a depth of 650 feet, so that a tube well even at that depth would not necessarily ensure a pure supply of water. The paper would form a valuable addition to the Society's transactions. Mr. Sutcliff had brought the subject prominently before the members and had caused the question to be well discussed.

THE END.

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